



# Air Accident Investigation Sector

## Incident

### - Final Report -

AAIS Case N°: AIFN/0016/2012

## Engine Hot Gas Leak

Operator: Abu Dhabi Aviation

Type: DHC-8-315Q

Registration: A6-ADB

Place of Occurrence: Abu Dhabi

State of Occurrence: United Arab Emirates

Date of Occurrence: 9 September 2012



Air Accident Investigation Sector  
General Civil Aviation Authority  
The United Arab Emirates

## Incident Brief

Name of the Operator	:	Abu Dhabi Aviation
Manufacturer	:	Bombardier Inc., Canada
Aircraft model	:	DHC-8-315Q
Nationality	:	United Arab Emirates
Registration	:	A6-ADB
State of Occurrence	:	The United Arab Emirates
Place	:	Departure from Abu Dhabi International Airport
Date and time	:	9 September 2012, 0649 Local Time

## Investigation Objective

This investigation was performed pursuant to the United Arab Emirates Federal Act No 20 (1991), promulgating the *Civil Aviation Law, Chapter VII- Aircraft Accidents*, Article 48, *CAR Part VI Chapter 3*, in conformity with *Annex 13* to the Convention on International Civil Aviation and in adherence to the *Air Accidents and Incidents Investigation Manual*.

**The sole objective of this Investigation is to prevent aircraft accidents and incidents. It is not the purpose of this activity to apportion blame or liability.**

The information contained in this Final Report is derived from the factual information gathered during the Investigation of the occurrence.

Reports are publicly available at:

<http://www.gcaa.gov.ae/en/epublication/pages/investigationReport.aspx>

## Investigation Process

The UAE AAIS were informed about the occurrence involving a scheduled passenger flight on a DHC8-300 Aircraft which returned to the departure airport, shortly after takeoff, via the Duty Investigator hot line, +971506414667, and immediately dispatched an Investigator to Abu Dhabi International Airport.

This occurrence was classified as an Incident<sup>1</sup> and in accordance with ICAO *Annex 13*, the UAE AAIS assigned an Investigation Team. The State of Manufacture and Design,

<sup>1</sup> This occurrence has been reclassified as an Incident after the Investigation revealed that there was no associated internal fire.



Canada, was notified and assigned an Accredited Representative to the investigation. The UAE AAIS will lead the investigation and issue the final Report.

Notes:

1. Whenever the following words are mentioned in this Report with first Capital letter, they shall mean the following:
  - Aircraft- the Aircraft involved in this Incident;
  - The Operator- Abu Dhabi Aviation
  - Investigation- the Investigation into the circumstances of this Incident;
  - Incident- this Incident referred to on the title page of this Report;
  - Report- this Incident Final Report;
  - Engineer- the Engineer involved with this Incident
  - Mechanic- refers to the Operator's Fitter. The UAE CAR-145 mentions mechanics and technicians only.
  - Supervisors- the Operator refers to the supervisors as aircraft senior LAEs.
2. Unless otherwise mentioned, all times in the Report are Local Time (Local time in UAE was UTC+ 4h);
3. Photos and figures used in this Report are taken from different sources and are adjusted from the original for the sole purpose to improve the clarity of the Report. Modifications to images used in this Report are limited to cropping, magnification, file compression, or enhancement of color, brightness, contrast, or addition of text boxes, arrows or lines.
4. This Report is based on the investigation of the Operator's fixed wing operations only.



## Abbreviations

<b>ADA</b>	Abu Dhabi Aviation
<b>AAIB</b>	Air Accidents Investigation Branch, the United Kingdom
<b>AAIS</b>	Air Accident Investigation Sector, UAE
<b>AFM</b>	Airplane flight manual
<b>ALF</b>	Aircraft looking forward
<b>AMM</b>	Aircraft maintenance manual
<b>AMO</b>	Approved maintenance organization
<b>AMP</b>	Approved maintenance program
<b>AMS</b>	Approved maintenance schedule
<b>ATC</b>	Air traffic control
<b>ATCO</b>	Air traffic controller
<b>ATPL</b>	Airline Transport Pilot License
<b>°C</b>	Degrees Celsius (temperature unit)
<b>CAA</b>	Civil Aviation Authority, the United Kingdom
<b>CAAP</b>	Civil aviation advisory publication
<b>CAP</b>	civil aviation publication, CAA, the United Kingdom
<b>CAR</b>	<i>Civil Aviation Regulation</i> of the United Arab Emirates
<b>CAR-OPS</b>	<i>Civil Aviation Regulation – Flight Operation</i>
<b>CASA</b>	Civil Aviation Safety Authority, Australia
<b>CAVOK</b>	Cloud and visibility okay
<b>CCM</b>	Cabin crewmember
<b>C of A</b>	Certificate of airworthiness
<b>CRM</b>	Crew resource management
<b>CVR</b>	Cockpit voice recorder
<b>CMR</b>	Certificate of maintenance review
<b>CPL</b>	Commercial pilot license
<b>DFDR</b>	Digital flight data recorder
<b>DHC</b>	de Havilland Canada (DHC)
<b>EASA</b>	European Aviation Safety Agency
<b>EC</b>	European Commission



<b>ELP</b>	English language proficiency
<b>EMP</b>	Equalized maintenance program
<b>ESN</b>	Engine serial number
<b>EU</b>	European Union
<b>FAA</b>	Federal Aviation Administration, the United States
<b>FC</b>	Flight cycles
<b>FDR</b>	Flight data recorder
<b>FH</b>	Flight hours
<b>FRM</b>	Fatigue risk management
<b>FRMS</b>	Fatigue risk management system
<b>ft</b>	Feet
<b>GCAA</b>	General Civil Aviation Authority of the UAE
<b>ICAO</b>	International Civil Aviation Organization
<b>IFTB</b>	In-flight turn back
<b>IIC</b>	Investigator in charge
<b>LT</b>	Local time
<b>LAE</b>	Licensed aircraft engineer
<b>LH</b>	Left hand
<b>MEMS</b>	Maintenance Error Management System
<b>MME</b>	<i>Maintenance Management Exposition</i>
<b>MoC</b>	Management of change
<b>MOE</b>	<i>Maintenance organisation exposition</i>
<b>MOS</b>	<i>Manual of standards</i>
<b>MRO</b>	Maintenance repair organization
<b>MSN</b>	Manufacturer serial number
<b>NPA</b>	<i>Notice of proposed amendment</i>
<b>NTSB</b>	The National Transportation Safety Board of the United States
<b>OMAA</b>	Abu Dhabi International Airport
<b>OMAS</b>	Das Island Airport
<b>PH</b>	Postholder
<b>P&amp;WC</b>	Pratt and Whitney Canada



<b>QNH</b>	Barometric pressure adjusted to sea level
<b>QRH</b>	<i>Quick reference handbook</i>
<b>RH</b>	Right hand
<b>SHIR</b>	Safety Hazard Investigation Report
<b>SMS</b>	Safety management system
<b>S/N</b>	Serial number
<b>SOP</b>	Standard operating procedures
<b>SR</b>	Safety recommendation
<b>STOL</b>	Short takeoff and landing
<b>TBO</b>	Time between overhaul
<b>TIB</b>	<i>Technical information bulletin</i>
<b>TSO</b>	Time since overhaul
<b>TSN</b>	Time since new
<b>UAE</b>	The United Arab Emirates
<b>UK</b>	The United Kingdom
<b>USA</b>	The United States of America
<b>UTC</b>	Co-ordinated Universal Time
<b>VFR</b>	Visual flight rules



## Synopsis

On 9 September 2012, a Bombardier DHC-8-315Q Aircraft, registration A6-ADB, operated by Abu Dhabi Aviation, departed from Abu Dhabi International Airport (OMAA) at 0645 LT on a scheduled 35-minute passenger flight, to Das Island Airport (OMAS) with 49 persons on-board. After several minutes inflight, and before reaching 5,000 feet, a passenger informed the cabin crewmember about signs of paint blisters on the right hand (RH) engine inboard panel, as seen through the cabin window.

The passenger's observation was confirmed by the co-pilot who informed the Commander of a possible engine fire. A PAN was declared and OMAA air traffic control (ATC) gave an immediate clearance for landing. Cockpit indications were normal but the crew decided to return to the airport due to the possibility of an engine fire. Unknown to the crew and passengers, the same condition also existed on the left hand (LH) engine.

The Aircraft landed uneventfully and the airport fire service confirmed that there was no sign of fire. No injury was reported among the passengers or crewmembers.

The Air Accident Investigation Sector determines that the cause of this Incident was the failure to re-install the LH engine igniters on both engines following maintenance action on the engines. The maintenance error resulted from a number of contributing factors.

Contributing factors are the findings in section 3 of this Report and identify factors related to un-recorded work, performing work on the aircraft without a reference, quality management oversight, personnel fatigue, duty times and SMS implementation.

Safety actions taken by the Operator can be found in section 4.2 of this Report.

The AAIS has addressed a total of 14 Safety Recommendations, 8 to the Operator, and 6 to the GCAA, based on the safety issues identified during this Investigation. Safety recommendations were issued concerning identification of critical tasks, human factors training, risk mitigation, cabin safety, quality audits, documentation, duty times, fatigue risk management scheme, data collection, and sharing of maintenance error information.

The safety recommendations can be found in section 4.3 of this Report.



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# 1. Factual Information

## 1.1 History of the Flight

On 9 September 2012, a DHC-8-315Q Aircraft operating a scheduled and regular passenger service, with a scheduled departure time of 0635 LT, between Abu Dhabi International Airport (OMAA) and Das Island Airport (OMAS), declared a PAN-PAN<sup>2</sup> and returned to OMAA. The turnback resulted from a passenger observation, subsequently confirmed by the co-pilot, of a deteriorating condition due to uncontrolled escaping hot engine gases that existed on the inboard side on the right (RH) inboard engine nacelle panel.

The Aircraft, which was owned and operated by the Operator, was one of three that was contracted to an oil company to transport passengers and cargo to Das Island, which is located in the Arabian Gulf, approximately 196 kilometers from, and West North West (WNW) of OMAA airport.

In preparation for the flight, the two cockpit crewmembers and one cabin crewmember (CCM) reported on time, at 0600 LT, and after reviewing the flight plan and weather report, proceeded to the Aircraft. Three flights were planned for the crew on this day, and the occurrence flight was the first of the day for both the Aircraft and the crew.

The most recent flight of the Aircraft, prior to the Incident flight, took place on the previous day, 8 September 2012. Following this flight, maintenance work was performed by the Operator's engineering team during the night stop at OMAA.

Before departure of the Incident flight, the co-pilot performed the walk-around with no findings. The departure fuel was 4,200 kilograms, the estimated flight time 35 minutes and the weather was clear with a temperature of 29°C.

The flight crew completed their procedural checks, during which time the 46 passengers boarded. Both engines were started, and at approximately 0635 LT taxi clearance was given from the parking stand located next to the passenger terminal building. The crew was cleared to taxiway to the holding point at intersection Echo 6 and then given clearance for a rolling takeoff from runway 13R. The Aircraft became airborne at 0645 LT with the Commander performing the pilot flying (PF) tasks.

During the engine starts, a passenger<sup>3</sup> seated at row 6 RH side, had his attention focused on the RH engine and saw fluid<sup>4</sup> coming from the engine. As the Aircraft began to taxi, he could see signs of discoloration of the paint and fumes being emitted from the vents located on the panel. Initially he thought it may have been due

<sup>2</sup> PAN-PAN is an international radiotelephony urgency signal. Preferably spoken three times, it indicates a condition that concerns the safety of an aircraft or another vehicle, or of some person on board or within sight, but that does not require immediate assistance.

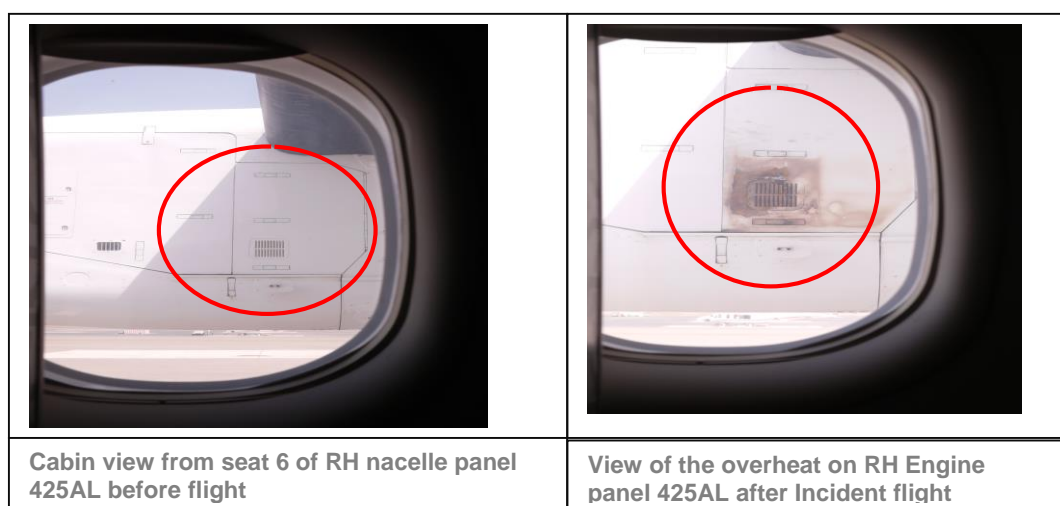
<sup>3</sup> The passenger, a mechanical engineer by profession, had flown in the same night from his home country in order to board the early morning flight to Das Island. As no seats are pre assigned for this short flight, the said passenger choose a window seat on the right hand side of the Aircraft at row 6. Even after his overnight flight, he remained awake and observed the passenger safety announcements in preparation for the flight. From his seat he could see the RH engine enclosure panels, the propeller and parts of the landing gear.

<sup>4</sup> The fluid the Passenger was seeing was residual fluid from the engine compressor wash performed by the aircraft maintenance staff during the night stop.

to some residual fluid within the compartment and he thought that after a short time it should subside. However as the Aircraft continued its short taxi for takeoff, he noticed that the fumes were continuing and the color of the panel was changing from white, its original color, to brown and then to black.

The passenger tried to draw the attention of the CCM by waving his hand but the CCM could not attend since the Aircraft was already on its take-off roll from runway 13R.

Shortly after takeoff, with the seat belt sign on, the CCM attended to the passenger as a result of his persistent calling. As the CCM could not identify and determine the seriousness of what the passenger had observed, he immediately went to the cockpit and mentioned to the flight crew that "There was something wrong." on the RH engine inboard nacelle. The Aircraft was still in the initial climb to 5,000 feet.



**Figure 1. RH Engine Inboard Nacelle Panel 425AL**

As stated by the flight crew, while passing 2,300 ft altitude, and as the passenger was beginning to become distressed, the co-pilot was requested by the Commander to leave his seat and investigate the persistent concerns made by the passenger. The co-pilot said that he observed from the passenger cabin window that the inboard RH engine nacelle had signs of a bright light within the compartment, indicating a possibility that there was a fire behind the panel. The paint on the panel was also blistering and bare metal was exposed.

The co-pilot returned to his position in the cockpit and he informed the Commander of his perception of a possible fire in the RH engine nacelle. No fire or overheat warning was generated in the cockpit as a result of the uncontrolled escaping hot gases at any time during the flight. However, as a result of the visual observations of the co-pilot, the Commander decided to immediately return to the departure airport.

During the climb from 4,000 to 5,000 ft, parallel to runway 13R, the flight crew informed ATC about signs of a fire and, simultaneously, declared a PAN-PAN. The Commander instructed the CCM to prepare the cabin for landing and to inform the passengers that they were returning to OMAA for a normal landing.



Unknown to the flight crew and the passengers, the same condition was developing in the LH Engine nacelle but was not visible, as the location of the nacelle vent panel was on the outboard side on the LH engine nacelle.

After the PAN-PAN declaration, ATC alerted the airport fire and rescue service and gave the Aircraft a priority landing, diverting all other air traffic.

A Visual flight rules (VFR) two engine-landing was performed and the Aircraft touched down, uneventfully, at about 0655 LT, on RWY 13R. The Commander immediately vacated the runway via taxiway Echo 10 and paused there in preparation for an Aircraft emergency evacuation, if required. The RH engine was shutdown, after which the airport fire services approached the Aircraft.

Upon confirmation by the fire service that there was no evidence of fire, the crew resumed taxiing, using the LH engine, to the passenger terminal parking stand.

The total flight time was approximately 10 minutes and total time from chocks-off to chocks-on was 31 minutes.

During the crew debriefing at the Operator's control center, the flight crew were informed that a similar condition had also existed on the LH Engine.

There were no injuries suffered by the passengers or crew members.

## 1.2 Injuries to Persons

**Table 1. Injuries to persons**

Injuries	Flight Crew	Cabin Crew	Other Crew On-board	Passengers	Total On-board	Others
Fatal	0	0	0	0	0	0
Serious	0	0	0	0	0	0
Minor	0	0	0	0	0	0
None	2	1	0	46	0	0
<b>TOTAL</b>	<b>2</b>	<b>1</b>	<b>0</b>	<b>46</b>	<b>49</b>	<b>0</b>

## 1.3 Damage to Aircraft

Inspection revealed that there was localized overheat damage as a result of hot engine gases escaping through an open igniter boss on the engine casing. The hot gas was impinging on the nacelle, engine case drain line and engine support strut.

The following photos were taken shortly after the incident and the findings were similar on both engines.

<p>Overheat damage on and paint blisters on engine external panel 415AL and 425AL</p>	<p>Overheat damage on Case Drain Line caused by hot gases emitted from open Igniter boss – same on both engines</p>
<p>Engine Support Strut heat damage caused by hot gases emitted from open Igniter boss – same on both engines</p>	

**Figure 2.** The 3 photos show the overheat damage

Several parts on both engines exhibited signs of overheat damage. Engine struts located within the compartment, fire seals, hoses, clamps, fire detector support grommets, access panels, igniter harness and fire detectors.

#### 1.4 Other damage

There was no other damage to property or to the environment.

#### 1.5 Personnel information

##### 1.5.1 The flight crew

From the records provided, both pilots were current and had the required rest prior to the Incident flight.





**Table 2.** Qualifications of the flight crew

Crewmember	Commander	Co-pilot
Type of license	Valid ATPL	Valid ATPL
Issuing State	UAE	UAE
Medical class	Valid Class 1	Valid Class 1
Total flying time (hours)	9500	2150
Total commands on all types	4500	885
Total on type	4500	1100
Total last 30 days	60	54
Total last 24 hours	Off-duty	Off-duty
Total on type last 30 days	48	75
English language proficiency	6	6

During the interview with the Investigation, the flight crew commented that in their previous flight experience, they have received passenger concerns about the possible sight of smoke exiting through the engine nacelle vents. They explained that this is considered normal. With this Incident, they initially assumed that what was seen by the passenger was the same and did not warrant any concern. Due to the persistence of the passenger the crew reacted positively and the co-pilot left his seat to investigate, at the direction of the Commander.

### 1.5.2 The cabin crew

The male cabin crewmember held a valid UAE GCAA crewmember certificate and a flight cabin attendant licence, and had flown to Das Island many times before as part of his job.

During the interview, the cabin crew member stated assistance was required from the cockpit crew as he could not make a judgement on identifying what the passenger had attracted his attention to.

The cabin crewmember added that as part of CRM training, it might be appropriate to have this occurrence mentioned, and how best to handle such situations in the future, especially as it occurred during a critical phase of the flight when the flight crew were busy.

He also added that the before take-off passenger safety briefing<sup>5</sup>, that is usually initiated after the passenger doors are closed, was given while the Aircraft was taxiing. Due to the noisy cabin environment caused by the running engines and propellers he was not sure how effective safety briefings are as they are inaudible to all passengers. In addition, he added that the briefing is given in the English language and he was not sure if all passengers could understand the English language.

<sup>5</sup> Required as per CAR-OPS 1.285



### 1.5.3 The on-duty maintenance Engineer

The on-duty maintenance Engineer, who was responsible for the shift (1330 to 2200 LT) on 8 September 2012, held the appropriate aircraft maintenance engineer license (AMEL) issued by the GCAA. He also possessed a valid company authorization to certify aircraft maintenance work performed on the Aircraft type.

He had many years of experience on the Aircraft type and joined the Operator, on contract from another country, about four years before the Incident date.

In addition to his normal responsibilities as a certifying engineer, he assigns and supervises maintenance work; he is responsible for ensuring that all Aircraft maintenance work performed during his shift is certified in the routine/non-routine cards and in the maintenance log book, as per the Operator's maintenance procedures. He is also responsible for electronic entry of all routine work and defect rectifications into the Operator's database system called Russell Adams (RUSADA). During the post-incident interview, the Engineer, as well as other staff, stated that this software was new to them and many of the staff members were still learning how to use it. In addition, there was no evidence presented to the Investigation as to whether the maintenance staff had been trained and were competent to use the software properly.

The Operator's approved working days for the Engineer followed a pattern of 56 continuous days on-duty followed by 28 days off-duty. The Engineer had resumed work on 6 August 2012 following annual leave. Thereafter, and until the Incident date, his planned roster was to work an average of 8.5 hours per day for 32 days with 2 staggered days off. The shift that he worked on 08 September 2012 was his 3<sup>rd</sup> shift working from 1330 to 2200 LT and he was responsible for 4 of the Operator's DHC-8 aircraft. On 7 September 2012, due to operational requirements he worked from 1330 LT, and finished work at 0130 LT on 8 September.

A review of the Engineer's file, which was kept by the Operator's quality department, did not reveal significant findings.

### 1.5.4 The passenger

The passenger, a mechanical engineer by profession, who raised the concerns of the deteriorating condition of the nacelle, was resuming duty at Das Island after vacation. He stated that he had travelled this sector, Abu Dhabi to Das Island many times.

He mentioned during the Investigation interview that due to his awareness of safety at the work environment, he intentionally was looking at the RH engine and became worried as he saw fluid coming from the engine as it was started. His concerns increased as the color of the panel started to change during taxi. Due to his assertiveness and persistence, he continued to signal for the CCM attention.

During the interview he also mentioned that the cabin safety briefing over the Aircraft passenger announcement system, performed by the CCM, was difficult to hear<sup>6</sup> as the safety announcement was done whilst the engines were operating.

<sup>6</sup> Reference to CAR-OPS 1.695 Public address system under section (b) states that 'The public address system required by this paragraph must: - (5) Be audible and intelligible at all passenger seats, toilets and cabin crew seats and work stations.'





## 1.6 Aircraft Information

### 1.6.1 General information

The Bombardier Dash 8, previously known as the de Havilland Canada (DHC) Dash 8, or DHC-8, is a two flight crewmember, twin-turboprop, medium range aircraft introduced by DHC in 1984 and is now produced by Bombardier Aerospace. Models delivered after 1997 have cabin noise suppression and are designated with the prefix, "Q".

### 1.6.2 Aircraft Data

Table 3 illustrates general Aircraft information

Table 3. Aircraft Data	
type and model:	DHC-8-315Q
Manufacturer:	Bombardier Inc., Canada
MSN:	650
Max TO / Ldg Mass (kg):	19505 / 19051
Date of delivery :	4/Oct/2007
TSN (hrs) / CSN (cycles)	6262 / 11733
Nationality and registration mark:	United Arab Emirates, A6-ADB
Name of the Operator:	Abu Dhabi Aviation
Aircraft certificates	All Valid at the time of the Occurrence
CMR date:	Valid
Last C-check date, FH, and FC:	6/May/2010, at 2972 / 5546
Last Equalized Maintenance Program (EMP) Check: Date/FH/FC	26/May/2012 at 5853 / 10979
Last daily check date, FH / FC	8/Sep/2012 at 6261.55 / 11731
Engines	Two Pratt and Whitney PW123E

### 1.6.3 Engines and Propellers

The Pratt and Whitney PW123E engine is a two-spool, centrifugal-flow, free-turbine turboprop engine rated at 2380 shaft horsepower.

Both engines are wing mounted and drive a four-blade Hamilton Sundstrand constant speed propeller, which can be feathered and reversed.

The first spool is a single low pressure (LP) centrifugal compressor which is shaft driven by a single LP turbine. The second spool is a high pressure (HP) centrifugal compressor, also shaft driven, by a single HP turbine. Power is provided to the propeller, via a reduction gear box, by a two stage free power turbine (PT) located at the rear of the engine. This shaft rotates clockwise and runs internally within the LP shaft, which in turn rotates anticlockwise within the clockwise rotating HP shaft. Each shaft is supported by various bearings throughout the engine.

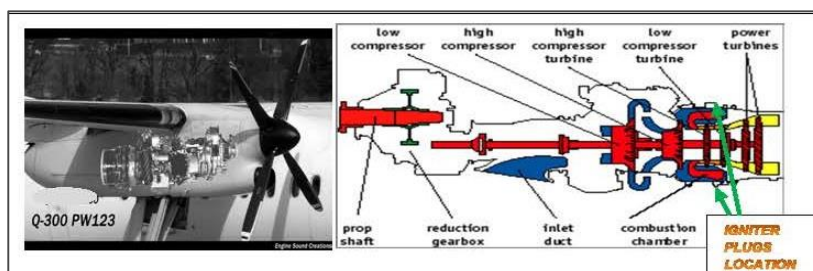


Figure 3. Engine PW123E basic schematic

Table 4 illustrates general information about the engines and propellers fitted to the Aircraft at the time of the Incident:

Table 4. Aircraft engines and propeller data						
Subject/Position	Manufacturer	Model	Serial Number	Time Since New-Hours	Time Since Fitted-Hours	Date Installed
ENGINE LH	Pratt & Whitney, Canada	PW123E	AR-005	8240:25	218:45	11/Jul/2012
ENGINE RH	Pratt & Whitney Canada	PW123E	AW-0135	5478:50	3:25	7/Sep/2012
PROPELLER LH	Hamilton Standard	14SF-23	961116	12875:40	1259:20	31/Oct/2011
PROPELLER RH	Hamilton Standard	14SF-23	961115	12979:45	434:30	18/May/2012

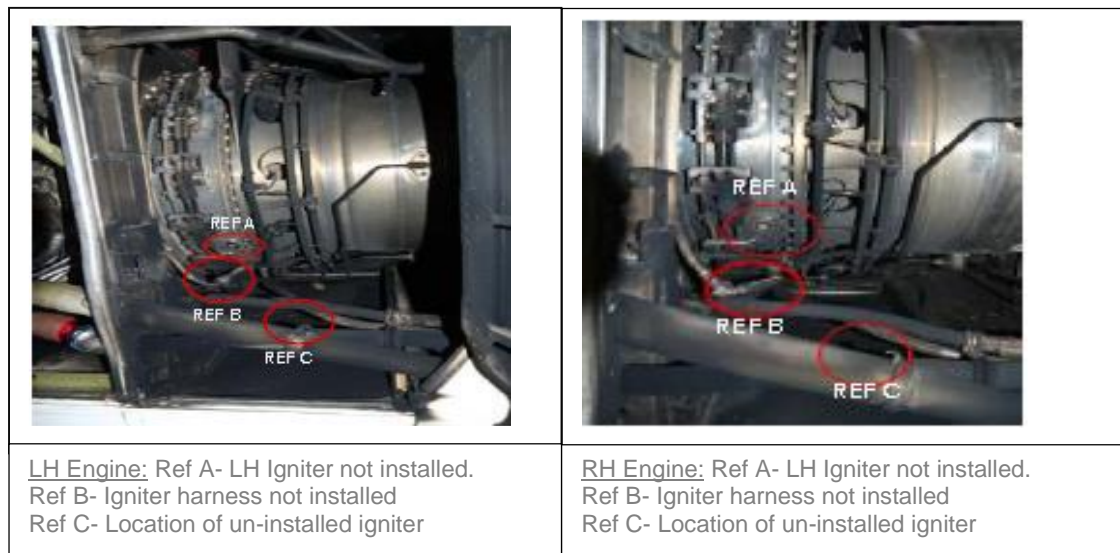
#### 1.6.4 Inspection of the Aircraft after the Incident

Inspection and defect troubleshooting by the Operator maintenance staff after the Incident revealed the following on both engines:

1. The source of the escaping hot engine combustion gases (the co-pilot mentioned seeing a fire on the RH engine) was coming from inside the compartment behind access panel 415AL of the LH engine, and panel 425AL on the RH engine. These panels enclose the engine hot section.
2. The latches of the access panels had to be forced open due to the effects of the overheating.
3. Upon opening the panels, it was confirmed that there had been an escape of hot engine combustion gases through an open port on the hot section of the engine. The open port diameter, approximately 0.5 inches, is where the igniters are installed.
4. The LH engine igniter was not fitted to the open port. The igniters were removed on 8 September 2012 by the Operator's maintenance staff as part of the requirement to perform an engine turbine water wash.

5. The LH igniters from both engines were found lying inside the engine compartment.
6. The electrical harnesses that connect to the igniters were not connected.
7. Evidence of black soot indicating signs of overheating was found within the engine compartment including on the structure and tubings.
8. No signs of overheating were observed on the compartment fire detectors, which were located approximately 16.5 inches from the open port.
9. The RH igniter plugs and harnesses on both engines were intact and installed.

The following photos were taken shortly after the incident and the observations were similar on both engines. Identification is mentioned based on looking from the aft of the Aircraft looking forward (ALF).



**Figure 4.** Photos showing inside the LH side of both engines

### 1.6.5 Operator's engine wash procedure

Information from the Operator indicated that engine performance and the on-wing life of the engine was affected negatively as a result of the local environment in which they operated. This prompted the Operator to introduce, based on the engine manufacturer recommendations; engine performance enhancement water washes in order to extend the life of the engines on wing. The references for the washes are in the engine manufactures manual, *P&WC maintenance manual, chapter 72-00-00*.

The engineering document<sup>7</sup>, *Task A7200/01*, used as a reference by the Operator's maintenance staff provided details on how to carry out engine turbine water

<sup>7</sup> Operator reference A7200/01- *Engine Turbine Wash*, dated May 2009. See [Appendix](#) of this Report.



washing as per the P&WC manual<sup>8</sup>, with the Operator opting for method 2 which is stated on the task reference.

This task was not included in the Operator's GCAA approved maintenance program, but was controlled by the Operator's planning department. The work was planned after the last flight of the day, normally during the night stop, at its base facility in Abu Dhabi. At the end of the work accomplishment, the task card was signed off by the mechanic, and then certified by the engineer.

As per the Operator's comments, this task, since its introduction in 2009, had resulted in an improvement in engine performance and extended the engine life on-wing, thus increasing the time before engine overhaul (Time between overhaul 'TBO').

When the washes were implemented, the Operator's maintenance planning department issued the required documentation, *Task A7200/01*, for reference and as a sign-off confirming that the work had been accomplished. However, in 2011, even though the engine washes continued, the referenced *task card 7200/01* was withdrawn and replaced with another procedure *EGEN F/W 11*.

As explained by the Operator, due to the engine washes being carried out daily on both engines of each of the four DHC-8 aircraft, there was a considerable amount of paperwork for the maintenance staff to certify. Thus, a decision was taken, and accepted by the Quality Department Management, that in order to reduce the volume of paperwork a new procedure called *Procedure Number EGEN F/W 11*<sup>9</sup> was introduced from December 2011. This procedure was not a sign-off document and required that the engine turbine washes would be certified in the aircraft technical log book by the certifying engineer by making an entry as stated;

The entry in the aircraft tech log was:

“Defect: Engine turbine wash required.

Action Taken: "Engine turbine water wash c/o IAW P&WC MM  
72-00-00 Engine cleaning Step C, Turbine water wash,  
Method 2.”

This statement would then be certified by the approved engineer without any signature by the mechanic assisting the engineer.

The procedure *EGEN F/W 11* was still being used when the Incident occurred.

#### 1.6.6 P&WC manufacturer recommended internal engine wash

The following are the recommended internal engine washes from the engine manufacturer and are performed during the on-wing life of the engine. As per the manufacturer, the washes removed atmospheric pollutants that may contaminate the engine gas path, which can lead to a build-up of deposits on airfoils, the initiation of corrosion, sulphidation or performance deterioration:

1. Compressor Desalination Wash

<sup>8</sup> P&WC maintenance manual chapter 72-00-00.

<sup>9</sup> See Appendix in this Report for *EGEN F/W 11*.



Used to remove salt deposits from the compressor blades, which can cause corrosion, however light dirt deposits may also be removed. Wash fluid is a drinking quality water and is injected at a controlled pressure into the engine intake using either an installed compressor wash ring or a hand held wash wand.

## 2. Compressor Turbine Desalination Wash

Used to remove salt deposits from the compressor turbine blades and stator. Salt build-up can cause sulphidation (a reaction between the salt and sulphur from the fuel). This wash is done immediately following a compressor desalination or performance recovery wash as contaminants will be transferred from the compressor to the hot section during compressor desalination or performance recovery wash. Wash fluid is a drinking quality water and is injected through a wash tube inserted through one of the igniter ports. The igniter plug is removed in order to insert the wash tube.

## 3. Compressor Performance Recovery Wash

Used to remove more sticky deposits which cannot be removed during normal desalination washes, item 1 and 2 above. For this wash, an approved detergent is used instead of the water only fluid and the wash is performed when engine performance loss is noticeable, or when trend monitoring dictates. Wash fluid is injected into the engine intake using either an installed compressor wash ring or a hand held wash wand. A water rinse of both the compressor and compressor turbine is required following the detergent wash.

The compressor turbine wash procedure, item 2 above, requires that after opening engine nacelle access panels 415AL and 425AL, the LH igniter electrical harness is to be disconnected and then the corresponding igniter plug removed<sup>10</sup>. The opening created by the removal of the igniter plug is where water under pressure is introduced to the engine turbine via an in-house assembled engine wash rig connected to a wash nozzle that is placed inside the open port (boss). Once the temperature of the engine is below 65 °C, each engine is motored at 10-25% Ng speed for approximately 20 seconds and during this motoring, water is introduced into the turbine from the rig via the wash nozzle. After the rig is turned off, the engine would then be motored for another 30 seconds to disperse the excessive water within the engine.

Upon normalizing the engine including the installation of the igniter plug, an engine ground run is performed, but only if the engine is not started within the next 12 hours. The *P&WC maintenance manual* gives the engine run after this wash as optional. As most of the washes took place during the late shift, and the aircraft normally flew in the early morning, the first engine starts would normally be during the next scheduled flight for the aircraft.

### 1.6.7 Incident Aircraft additional compressor engine wash

A review of the maintenance records did not reveal that an engine compressor desalination water wash task was being performed as there were no recorded maintenance entries.

<sup>10</sup> The RH engine igniter plugs are not disturbed for this procedure. Both engines RH igniter plugs were installed on the Incident Aircraft and was not disturbed.





This wash was instituted by the Operator's aircraft maintenance supervisors. There was consensus amongst the supervisors that the on-wing life of the engine could have been extended by implementing the additional wash. Their intention was to trial the task on the Incident Aircraft LH engine only, as that engine had been installed in July 2012. This wash was to complement the already existing daily requirement mentioned in task *Procedure Number EGEN F/W 11*.

However, this additional wash task was neither included in the Aircraft maintenance program, nor was it controlled by the maintenance planning department.

The additional engine compressor desalination wash task was first performed in July 2012, and continued at every night stop at the main base until the occurrence of the Incident. No evidence was provided to the Investigation that a task card for a compressor wash had been issued by the maintenance staff supervisors. Furthermore, there was no evidence that the work performed was documented and signed off by a certifying engineer. In addition there were no entries made into the Operator's RUSADA that this wash had been performed.

As mentioned by the supervisors, the information on this new engine wash requirement was relayed verbally to the other maintenance staff. There was no evidence as to who had been informed and, as stated to the Investigation, staff who were on annual leave were not aware that a new engine compressor wash task had been implemented on the Incident Aircraft.

According to the Operator's management, regular meetings were held for engineering and maintenance staff. These meetings were called 'toolbox meetings' and they provided an opportunity for staff and management to address safety, technical and other general issues.

There was no evidence that a '*read-and-sign*' document had existed to highlight, or bring to the attention of all staff, any change in procedures or any other important technical or non-technical issues. Thus, the Investigation could not verify if the additional compressor engine washes was mentioned during the 'toolbox meetings'. The Operator's responsible management stated that that they were not aware of the new task.

#### **1.6.8 Aircraft maintenance performed on 8 September 2012**

On 8 September 2012, the Aircraft had a scheduled night stop at the Operator's main facility at Abu Dhabi Airport.

The work performed on the Aircraft during the night stop included the daily check, two defects reported by the outgoing flight crew, a maintenance requirement for an aircraft external wash and internal washes of both engine. One defect required toilet servicing and the other defect required adjustment of the nose gear steering system cables, which meant that the Aircraft had to be inside the hangar.

During the time that the Aircraft was inside the hangar, both engines were prepared for turbine engine water washes, as per the Operator's requirements as detailed in *Procedure Number F/W 11*<sup>11</sup>. This required access panel 415AL on the LH engine and 425AL on RH engine nacelles to be opened by releasing three latches,

<sup>11</sup> Mentioned in section 1.6.5 of this Report.



after which the LH engine igniter electrical harness on each engine is disconnected, and then the corresponding igniter plug is removed<sup>12</sup>.

The Engineer had performed the task of preparing both engines for the turbine water wash. The LH igniter plug was removed from each engine, and left inside the engine compartment. No reference document was used, and like the Engineer, other maintenance staff mentioned during the post-incident interviews that they would carry out this task from memory.

It was noted during the Investigation that no telltale streamer is required to be used by the Operator's maintenance staff to identify that an item requires maintenance intervention before the next flight that was disturbed during maintenance work in areas not easily visible, or behind closed panels. For the work performed on the Incident Aircraft, no telltale streamer was used for the removed igniters.

The Aircraft external wash, as well as the engine turbine washes required that the Aircraft be outside the hangar. After rectification of the nose wheel steering defect, the Aircraft was towed out from the hangar.

The sequence of the work planned by the Engineer was for the external aircraft wash to be done first, and thereafter the engine washes. In preparation for the external Aircraft wash all fuselage panels and engine access panels were closed, which included engine panels 415AL and 425AL.

During the external wash of the Aircraft, which was performed by the assigned maintenance mechanics, the Engineer returned to the document control room in order to complete the necessary paperwork, including data entries into the RUSADA.

After the aircraft external wash was completed, another two mechanics<sup>13</sup>, who had completed their assigned work on two other DHC8 aircraft, volunteered to perform the engine washes.

These two mechanics had been made aware, verbally, that the Aircraft had a new requirement for engine washing. During the Investigation, it was revealed that there was a misunderstanding as they were unsure if the requirement was for a compressor only, turbine only or compressor and turbine wash combined. As stated by the mechanics, the previous washes they had performed on this Aircraft's engines was that of compressor desalination washes only. Therefore, the mechanics prepared both engines for compressor water washes by removing the single access plug<sup>14</sup> ([figure 5](#)) on the external engine compressor casing. The compressor wash does not require engine nacelle panels 415AL and 425AL to be opened, but does require another two adjacent panels, 413AL for the LH engine and 423AL for the RH engine to be opened in order to access these plugs.

<sup>12</sup> Each engine has two electrical igniters and both are externally mounted on the engine hot section. One igniter is located at approximately the 4 (RH plug) and 8 (LH plug) O'Clock positions on the engine. The igniters are supplied with aircraft electrical voltage during engine start by means of a electrical harness connected to the igniter.

<sup>13</sup> The 2 maintenance mechanics that performed the engine washes are different to the mechanics that washed the Aircraft.

<sup>14</sup> Pratt & Whitney Canada *maintenance manual* 72-00-00, fig 704.



**Figure 5.** Location of engine compressor wash plug

After they completed the compressor washes, the two mechanics normalized the engines' compressor plugs and sense lines, and closed both engines' panels. They then verbally informed the Engineer that the engine washes on the Aircraft were completed. As there was no documentation for the mechanics to sign or to refer to, the Engineer accepted their verbal confirmation, and assumed that the turbine washes and igniter plugs normalization were actioned. He did not carry out a physical inspection to confirm that everything had been refitted. It was noted by the Investigation that the mechanics who had performed the wash did not have the Operator's authorization to perform unsupervised engine washes.

The Engineer then signed off the work for the engine turbine washes in the maintenance log book, as stated in procedure EGEN F/W 11, "*Engine turbine water wash c/o IAW P&WC MM 72-00-00 Engine cleaning Step C, Turbine water wash, Method 2.*" and released the Aircraft to service. Their shift ended at 2200 LT and the Engineer made an entry in the shift handover that the aircraft was ready for the next flight.

The mechanics stated to the Investigation that the turbine water washes were not performed, and they did not have any reason to inspect the engine igniters. Thus, both igniters were not refitted to the engines prior to the Incident flight.

On the morning of 9 September 2012, another maintenance crew, including one of the mechanics who had worked on the Aircraft during the previous shift that ended at 2200 LT, reported for duty at 0600 LT, and released the Aircraft for the Incident flight.

#### **1.6.9 P&WC PW123 engine fire/overheat warning system**

There are two independent fire detection loops located within the engine compartment, for monitoring and indicating a fire or overheat condition to the flight crew<sup>15</sup>. Whenever the temperature within a zone reaches a predetermined value, a warning is triggered in the flight deck indicating an overheat or fire in the engine area.

Each system consists of two separate fire detection sensor loops, routed in parallel (each with a responder attached), a fire detection control unit, control switches and warning lights.

The loops are filled with gases that expand when exposed to a temperature increase causing a proportional increase in internal gas pressure. When the pressure reaches to a specified level, an alarm switch within the loop responder closes and triggers alarm circuits in the fire detection control unit. The fire detection control unit then sends signals to illuminate warning lights located on the cockpit fire protection

<sup>15</sup> De Havilland Dash 8 series 300 Aircraft Maintenance Manual 26-11-00 Rev at 2012.



panel (overhead panel) and on the glare shield panel. Warning lights also illuminate when a malfunction affecting either of the two systems occurs.

The engine igniters are located approximately 16 inches from the fire detector loops, as noted in figure 6, and are designed to trigger fire and/or overheat warnings when the detection loops are exposed to temperatures<sup>16</sup> between 177 and 221°C. As per the engine manufacturer, the temperature of the escaping hot gases at the igniter open port would have been approximately 500 degrees Celsius. However, during the Incident flight, no fire warnings were triggered.

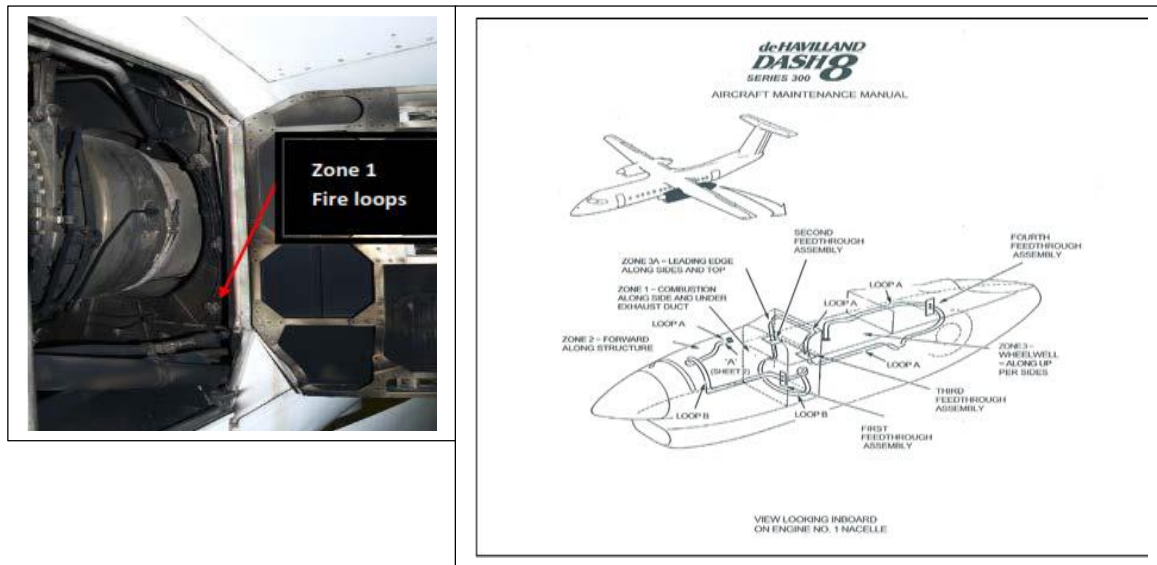


Figure 6. Location of Zone 1 Fire Detectors

#### 1.6.10 P&WC PW123 engine zones and cooling

The engine compartment is divided into zones. The zone where the uncontrolled hot gases were exiting through the igniter port during this Incident is numbered as zone 1. This zone comprises the engine hot end and tail pipe area, which also includes the combustion zone. Also, there is a continuous shroud surrounded by a firewall and this is manufactured using a fire proof material<sup>17</sup>.

<sup>16</sup> Meggitt Safety Systems Component Maintenance Manual 26-10-88 as received in October 2012.

<sup>17</sup> De Havilland Dash 8 series 300 Aircraft Maintenance Manual 75-20-00 dated 2012.

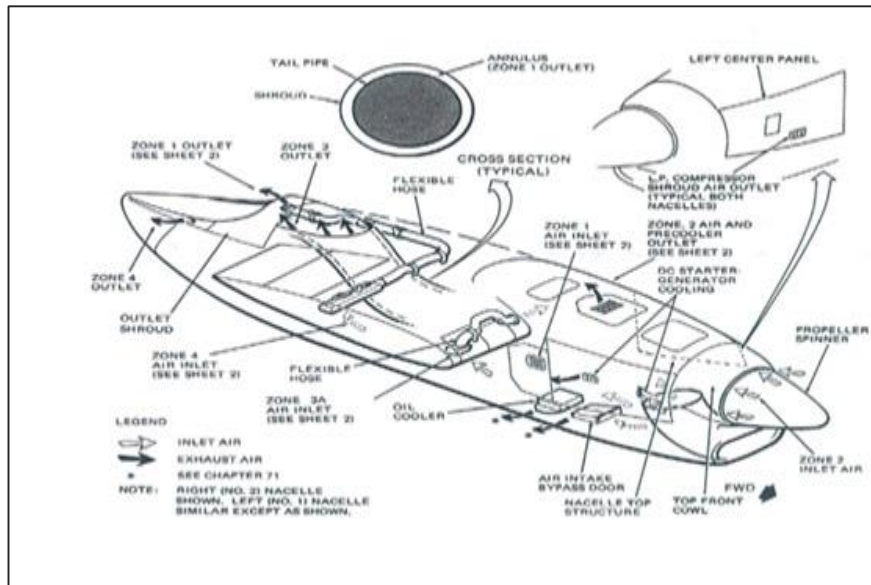


Figure 7. Engine zones and cooling airflow.

Zone 1 is cooled by ambient air, which enters the area via the forward facing louvers located on the nacelle access panels 415AL and 416AR for the LH engine and 425AL and 426AR for the RH engine. The ambient air is circulated within the zone to cool and ventilate the compartment. The air then exits from the annulus formed between the engine tail pipe and the compartment shroud.

As per the manufacturer of the engine, the temperature of the uncontrolled hot gases escaping from the open igniter ports could have reached about 500°C.

## 1.7 Meteorological Information

The weather during the operation of the flight was not significant to this Investigation. At the time of departure, the flight crew reported that the weather was CAVOK<sup>18</sup>, with a 5 knot wind speed at 120 degrees, and the temperature was 29°C.

## 1.8 Aids to Navigation

Onboard navigation aids were not a factor in this Incident.

## 1.9 Communications

All communications were normal and were not a factor in this Incident.

## 1.10 Aerodrome Information

Abu Dhabi International Airport (OMAA) has two parallel runways 13R/31L and 13L/31R. Both are 4,100 metres in length.

<sup>18</sup> CAVOK meaning: Ceiling and Visibility are OK; specifically, (1) there are no clouds below 5000 feet above aerodrome level (AAL) or minimum sector altitude (whichever is higher) and no cumulonimbus or towering cumulus; (2) visibility is at least 10 kilometres (6 statute miles); and (3) no current or forecast significant weather such as precipitation, thunderstorms, shallow fog or low drifting snow.



Both runways were available at the time of the Incident. The airport fire service department is fully equipped to manage any type of emergency.

Das Island Airport (OMAS) has a single runway 15/33 with a length of 1,078 metres and width of 30 metres.

Neither airport was a factor in this Incident.

### 1.11 Flight Recorders

The Flight Data Recorder (FDR) and Cockpit Voice Recorder (CVR) were removed from the Aircraft and successfully downloaded.

Both recorders were intact with no signs of external damage.

#### FDR Data:

Part number: 2100-6022-001. Serial Number: 306392

A review of the flight data did not indicate any abnormal parameters.

#### CVR Data:

Part number: 980-6022-001. Serial Number: CVR120-09497

The playback of the CVR did not indicate any abnormalities or warnings.

The parameters of the RH engine were compared with similar parameters recorded from previous flights with the igniters installed. No substantial differences in fuel flow and inter-turbine temperatures (ITT) were observed.

**Table 5. FDR data for the Incident flight**

Flight Phase	ITT	Fuel Flow (kg/h)	Airspeed
Taxi	530 to 550°C	300 to 310	N/A
Take off roll	685°C	1150	N/A
Climb	705 to 720°C	965 to 985	140 Kts
Descent	520 to 540°C	375	140 Kts
Touch down	515 to 530°C	N/A	110 Kts

### 1.12 Wreckage and Impact Information

Not applicable to this Investigation.

### 1.13 Medical and Pathological Information

For the Incident flight, medical and pathological information was not required. There was no medical condition reported to the Investigation that indicated the need to perform any additional investigation.

### 1.14 Fire

No external fire was involved in this Incident and the overheat condition within the engine compartment did not show any signs of additional ignition or burning.



### 1.15 Survival Aspects

Not a factor with this Incident.

The CCM prepared the passengers for an emergency disembarkation, as instructed by the Commander. Upon landing, and after confirmation by the fire services that there was no fire, all crew and passengers disembarked the Aircraft normally.

### 1.16 Test and Research

During the inspection of the Aircraft following the Incident, the Operator's maintenance staff tested the engine fire detector loops, as per the recommended aircraft maintenance manual procedures. The test performed did not identify any system abnormalities.

As there was a concern about the serviceability of the installed fire detectors, especially as there was no cockpit indications of any overheat, the affected fire detectors were removed and sent to the manufacture for bench tests against the designed specifications, and according to the overhaul manual. The tests did not reveal any anomalies.

The Operator's maintenance personnel also carried out testing of the aircraft engines ignition systems, and both systems operated normally.

### 1.17 Organizational and Management Information<sup>19</sup>

The Operator is approved by the GCAA and had the applicable air operator certificate (AOC) as well as approval to perform aircraft maintenance on several fixed wing and rotary wing aircraft types including the Bombardier DHC-8-315

Founded in 1975, the Operator is owned by private UAE nationals and the Abu Dhabi Investment Council. At that time, the company operated only two aircraft. In 2012, the Operator was certified by the GCAA to operate a fleet of helicopters (Augusta Westland AW139, Bell 412, Bell 212 and Bell 206), and fixed-wing aircraft (DHC-8).

Most of the company's business activity is in support of Abu Dhabi Offshore Oil and engineering and construction companies. Other business activities include medical evacuation, survey, aerial spraying of crops, air photography and charter operations.

Operator records indicate that they have been awarded The Safe Flying Award in the achievement of 600,000 safe flying hours. The award commemorated their Outstanding Operational and Maintenance Standards and made the Operator one of the three leading Bell Helicopter operators worldwide. In addition, the Helicopter Association International (HAI) presented the prestigious Platinum Programme of Safety Award to the Operator. It is presented to organizations that adhere to auditable criteria that demonstrate a commitment to a higher standard of safety, through the adoption of industry best practices.

Prior to 2008, over 800 personnel were employed by the Operator. This number included approximately 150 aircraft maintenance engineers. However, in 2008/2009, the Operator underwent a companywide restructuring which resulted in a reduction in headcount, including production staff supporting aircraft maintenance. This

<sup>19</sup> Information from the Operators' web site: <http://www.abudhabiaviation.com/about-us/overview.aspx>.



restructuring also reduced the staffing of the Safety Department and placed the safety functions under the Quality Department. The Quality Post Holder then assumed the overall SMS responsibilities. As indicated by the Operator during this Investigation, management of change associated with the reduction in staff was not performed.

## 1.18 Additional Information

### 1.18.1 Operator's procedures concerning critical tasks

Under the Operator's *maintenance organization exposition (MOE)*, certain aircraft maintenance tasks are identified as 'critical tasks'. It was noted that tasks associated with engine washing are not categorized as critical.

According to the UAE *Civil Aviation Regulations (CAR) Part V Chapter 3, CAR-145*, the organization is responsible for establishing procedures to minimize the risk of multiple errors, and to capture errors on critical systems. The organization is also required to ensure that no person is required to carry out, and inspect, a maintenance task that encompasses a sub-task of disassembly/reassembly of several components of the same type, fitted to more than one system on the same aircraft during a particular maintenance check. However, when only one person is available to carry out these tasks, the organization's work card or worksheet shall include an additional stage for re-inspection of the work by this person, after completion of all sub-tasks.

Furthermore, in the Operator's *MOE, section 2.23- Control of Critical Tasks*, it is mentioned that:

"In order to avoid the possibility of an error being repeated during disassembly/ reassembly of components of the same type fitted to more than one system, maintenance of this type is to be carried out as detailed below:

Whenever possible, different personnel are to be responsible for the disassembly/ reassembly of like components fitted to more than one system on the aircraft during a particular maintenance check. If circumstances dictate that only one person is available to carry out these actions then, as deemed necessary by the Engineering Director, a stage/ duplicate inspection shall be carried out by an independent engineer.

All stage/duplicate inspection shall be carried out in accordance with Company Procedure *GEN 39*."

The Operator did not consider that engine washes, and items removed for this task, required re-inspection by a second engineer.

### 1.18.2 Operator's internal company quality audits

Although the engine compressor wash task had started from middle of July 2012, two months prior to the Incident, and on every night stop, the obligations of the Operator, as a *CAR-M* and *CAR-145* certificated organization, did not highlight any concerns with documentation, maintenance sign-offs, entering data into RUSADA, or shift handover.

*CAR 145.65*: The organization shall establish a quality system that includes the following:



- "1. Independent audits in order to monitor compliance with required aircraft/aircraft component standards and adequacy of the procedures to ensure that such procedures invoke good maintenance practices and airworthy aircraft/aircraft components. In the smallest organizations the independent audit part of the quality system may be contracted when authorized by the authority to another organization approved under this Part or a person with appropriate technical knowledge and proven satisfactory audit experience who is specifically authorized by the authority for this task; and
2. A quality feedback reporting system to the person or group of persons specified in CAR 145.30(b) and ultimately to the Accountable Manager that ensures proper and timely corrective action is taken in response to reports resulting from the independent audits established to meet paragraph (1 above)."

#### 1.18.3 Operator's aircraft maintenance staff duty timings<sup>20</sup>

The Engineer and the mechanics who carried out the maintenance work on the Aircraft completed human factors and CAR-145 training as documented by the Operator. Thus, they were aware of the health and safety elements affecting their performance as well as the requirement of recording and sign-off for work performed on an aircraft.

During the Investigation interviews, the employees raised concerns related to shift rostering, especially the 56-days on-duty and resulting fatigue. They also mentioned workload versus available man-hours, shift hand-over, the effect of additional work and responsibilities due to the organizational restructuring, and data entry into the RUSADA system.

The Engineer's roster, as well the rosters of other maintenance personnel, requires them to work an 8.5-hour shift per day inclusive of 1 hour break, for 56 consecutive days, rotating between an early start day shift (E) from 0600 to 1430 LT and a late shift (L) from 1330 to 2200 LT. After 56-days on-duty, the employees are rostered off for 28 consecutive days leave. On the day of the Incident, the Engineer reported on-duty at 1330 LT, together with a licensed certifying engineer and three mechanics. The work for that shift included tasks on line maintenance, other planned aircraft work and rectification of reported snags on four other DHC-8 aircraft and preparation of the fleet for the next days' flights.

Duty timings for personnel who worked on the Aircraft:

1. The Engineer; It was noted that the Engineer was on his leave cycle that ended on 5 August 2012 and reported on-duty on 6 August 2012 for a new on-duty period of 56-days.

Prior to the day of the Incident, the Engineer worked a combination of shifts (shifts (E) and (L) for 32 days with 2 staggered days off. His duty on the 8 September 2012 was his 3<sup>rd</sup> shift (L), but on 7 September 2012 he stayed on-duty past midnight in order to complete an engine change task on the Incident Aircraft. The

<sup>20</sup> Most of the maintenance personnel worked; (E) Shift from 0600 to 1430 LT; (L) Shift from 1330 to 2200 LT.





Investigation could not determine how many rest hours the Engineer had before reporting on-duty on the same day, which started at 1330 LT. His planned roster after the day of the Incident was 15 consecutive duty days, followed by 28 off-duty days.

2. The certifying engineer; He was working his 3<sup>rd</sup> shift (L), prior to which he was on leave from 17 August to 5 September 2012. His planned roster was unique amongst all of the maintenance personnel in that the roster was a 4-days on-duty followed by 2-days off-duty roster.
3. Mechanic 1; Prior to 8 September 2012, he had worked a combination of shifts (E) and (L) for 21 days with 1-day off-duty. On that day, it was his last shift (L) in his 9<sup>th</sup> on-duty day without any rest. His next shift was (E) which was planned to start at 0600 LT on the next day (9 September 2012). Thereafter, he would have to continue working for a total of 13 days before getting one-day off-duty as per his September 2012 planned roster.
4. Mechanic 2; Prior to 8 September 2012, he had worked a combination of shifts (E) and (L) for 32 days with 2 days staggered off-duty. His roster continued into September for another 5 days before getting one-day off-duty.
5. Mechanic 3; 8 September 2012 was his 2<sup>nd</sup> shift (L) after returning from leave and his planned roster thereafter was another 10 consecutive days on- duty followed by a one-day off-duty.

There is no requirement per the GCAA regulations for a risk assessment of the potential hazards of maintenance staff working shift duties. It was noted that the Operator had no procedure for measuring and mitigating the effects of fatigue<sup>21</sup> due to the mentioned shift pattern.

#### 1.18.4 The Operator's safety management system<sup>22</sup>

*CAR Part X*<sup>23</sup> states that, "As of December 31<sup>st</sup> 2010, a UAE based Organisation who is certified under CAR-OPS 1, CAR-OPS 3, CAR-145 (Maintenance Organisation with Class A rating), CAR Part VIII, or CAR Part IX; shall show a complete compliance with this regulation by establishing a safety management system that is acceptable to the GCAA, maintaining it, and completing its implementation by establishing and complying with the requirements of this Part."

The elements of *CAR Part X* prescribe the requirements of the safety management system as follows:

<sup>21</sup> A sample for reference on management of fatigue can be made to <http://www.interdynamics.com/fatigue-risk-management-solutions/fatigue-risk-management-products/download-faid-demo/>

<sup>22</sup> In 2013, the Airline started using SMS Pro™ which is stated as: "an Internet or Intranet-based integrated safety management system designed to manage Safety, Security, Quality, and Compliance issues. This aviation safety management system (SMS) database software product has been designed to record, report, and analyzes accident, incident, and near-miss data.

<sup>23</sup> *CAR Part X*, dated 15 February 2011, Issue 2, Revision 0



“The safety management system shall be appropriate to the size, nature and complexity of the operations authorized to be conducted under its operations certificate and shall, at least, comply with the following requirements:

- (i) Identify safety hazards and assesses and mitigate risks
- (ii) Ensure that remedial action necessary to maintain an acceptable level of safety is implemented;
- (iii) Provide for continuous monitoring and regular assessment of the safety level achieved; and
- (iv) Aim to make continuous improvement to the overall level of safety.”

In May 2011, the GCAA raised an audit non-conformance that required Safety to be independent from Quality. In August 2011, in response to this non-conformance, the Operator appointed a new SMS postholder who was subsequently accepted by the GCAA in September 2011. A new Safety Department was created which marked the commencement of the SMS Planning and Implementation to comply with the GCAA requirements.

At the beginning of 2012, although there was a referenced SMS manual available, the appointed Safety Manager PH and his deputy were in the process of obtaining a GCAA-approved SMS manual which was work-in-progress due to the workload in the department. The GCAA did accept that the manual should be submitted before end December 2012, which was complied with. The GCAA also accepted that the Operator would have a phased approach of SMS implementation over 2 years, late 2012 to 2014.

Prompted by a GCAA audit finding, an internal organisation audit<sup>24</sup> was performed in May 2012, four months before the Incident flight, and this audit brought to the attention of the Operator’s senior management nonconformities related to SMS implementation, staffing issues within the Safety department, risk assessment not defined, safety hazard identification, safety audits and flight data monitoring.

All the internal audit findings were closed by the Operator three months before the occurrence (June 2012), with a comment after each corrective action to “review/monitor progress.”

In trying to understand the safety culture among the aircraft maintenance personnel, the Investigation was not presented with any analytical surveys. A safety culture survey of the flight crew was performed for in 2011.

<sup>24</sup> Operator Audit/Instance Number: INT/0047/001 – SMS dated 01<sup>st</sup> May 2012.





#### 1.18.5 Aircraft maintenance release and audits- ICAO and GCAA

Some of the references that give guidance on continued airworthiness of an aircraft, and auditing by an organization:

##### 1.18.5.1 ICAO Annex 6 Part 1, chapter 8

"8.1 Operator's maintenance responsibilities

8.1.1 Operators shall ensure that, in accordance with procedures acceptable to the State of Registry:

- a) Each aeroplane they operate is maintained in an airworthy condition;
- b) The operational and emergency equipment necessary for an intended flight is serviceable; and
- c) The certificate of airworthiness of each aeroplane they operate remains valid."

8.8 Maintenance release

8.8.1 A maintenance release shall be completed and signed to certify that the maintenance work performed has been completed satisfactorily and in accordance with approved data and the procedures described in the maintenance organization's procedures manual.

8.8.2 A maintenance release shall contain a certification including:

- a) Basic details of the maintenance carried out including detailed reference of the approved data used;
- b) The date such maintenance was completed;
- c) When applicable, the identity of the approved maintenance organization;
- d) The identity of the person or persons signing the release."

##### 1.18.5.2 CAR Part V, chapter 3 – CAR-145

Under the *CAR Part V, Chapter 3, CAR-145* the following is stated with reference to maintaining an airworthy aircraft and minimizing human errors:

*CAR 145.50- Certification of maintenance:*

"(a) A certificate of release to service shall be issued by appropriately authorized certifying staff on behalf of the organization when it has been verified that all maintenance ordered has been properly carried out by the organization in accordance with the procedures specified in CAR 145.70, taking into account the availability and use of the maintenance data specified in CAR 145.45 and that there are no non-compliances which are known to endanger the flight safety.



(b) A certificate of release to service shall be issued before flight at the completion of any maintenance.

CAR 145.65 Safety and quality policy, maintenance procedures and quality system:

(a) The organization shall establish a safety and quality policy for the organization to be included in the exposition under CAR 145.70.

(b) The organization shall establish procedures agreed by the Authority taking into account human factors and human performance to ensure good maintenance practices and compliance with this Part which shall include a clear work order or contract such that aircraft and components may be released to service in accordance with CAR 145.50.

1. The maintenance procedures under this paragraph apply to CAR 145.25 to CAR 145.95.

2. The maintenance procedures established or to be established by the organization under this paragraph shall cover all aspects of carrying out the maintenance activity, including the provision and control of specialized services and lay down the standards to which the organization intends to work.

3. With regard to aircraft line and base maintenance, the organization shall establish procedures to minimize the risk of multiple errors and capture errors on critical systems, and to ensure that no person is required to carry out and inspect in relation to a maintenance task involving some element of disassembly/reassembly of several components of the same type fitted to more than one system on the same aircraft during a particular maintenance check. However, when only one person is available to carry out these tasks then the organization's work card or worksheet shall include an additional stage for re-inspection of the work by this person after completion of all the same tasks. Maintenance organization must also establish procedures for duplicate inspections as per CAR Part V, Chapter 2, Section 9."

#### 1.18.6 GCAA audits of the Operator

An Investigation review was carried out on the audits as documented in the GCAA's Safety Affairs Sector.

In the audits, which were conducted during the period from 2010 to 2013, several findings were registered. Amongst them were findings related to SMS awareness, SMS training including SMS training for senior management, SMS



implementation as per *CAR Part X*, SMS department staffing, safety review, hazard identification, and flight data monitoring.

The Operator had satisfactorily closed all the audit findings and action taken was accepted by the GCAA inspectors.

The Investigation was not presented with evidence that a Management of Change (MOC) was carried out to determine safety risks associated with major organizational restructure prior to the staff reduction in 2008/2009. However, this MOC requirement was never raised by the GCAA during the subsequent audits between 2009 and 2011. In addition, the Investigation review could not determine if factors related to management of duty times and fatigue for aircraft maintenance personnel was audited.

#### 1.18.7 Data from GCAA ROSI on aircraft maintenance reports

In 2010, the GCAA introduced a *Civil Aviation Advisory Publication (CAAP) 22* enforcing online mandatory occurrence reporting called as 'Reporting of Safety Incidents (ROSI)'<sup>25</sup>.

As per *CAAP 22*, "The objective of the incident reporting, collection, investigation and analysis systems is to provide timely regulatory response in the interest of aviation safety. The incident reporting system is also an essential element of the overall GCAA centralised monitoring function."

From the ROSI data provided to the Investigation in 2013, due to the number of reports, the data was insufficient to make any reasonable deductions.

As a sample of ROSI data provided, listed are two examples:

1. The Operator had submitted a total of 14 reports through ROSI during the period from 2010 to 2012 (7 in 2010, 2 in 2011, and 5 in 2012). As there were limited reports in the ROSI file, no significant observations were made by the Investigation. For the fixed wing operations of the Operator, it is estimated that from 2010 to 2012, approximately 100,000 man-hours was available based on the 2012 head count of 27 aircraft maintenance personnel at the Operator's main base, Abu Dhabi,
2. Another UAE GCAA approved maintenance and repair organization (MRO) that produced about 4 million man-hours in aircraft maintenance over four years (2010 to 2013), had submitted a total of 17 reports (9 in 2010, 2 in 2011, 5 in 2012 and 1 in 2013). Most of the reports were related to overdue aircraft maintenance. However, some of the reports referred to issues related to maintenance errors, including human factors, with a mention of insufficient engineers for the workload, staff working long hours, fatigue, misleading documentation, and shift handover.

*CAAP 22, Appendix B- List of Examples of Reportable Incidents*, addressed fatigue for flight crew as a reportable incident. For aircraft maintenance personnel, there is no mention that fatigue is reportable.

<sup>25</sup> *CAAP 22* gives guidelines on what is required to be reported. This *CAAP* applies to all UAE operators operating in or outside UAE territory, and to the GCAA approved or certified organisations.



Currently, sharing of information is limited within the GCAA. It was noted by the Investigation that analytical reports related to trends or safety concerns related to maintenance errors collected from ROSI reports, or feedback from the aviation industry, is not available from the GCAA for the benefit of the aviation industry.

Voluntary reporting<sup>26</sup> of any safety concern has also been instituted by the GCAA, which is covered under *GCAA CAAP 57. VORSY, Voluntary Reporting System*, which commenced in October 2011. The Investigation did not find any *VORSY* reports submitted by the Operator's personnel.

#### 1.18.8 Aircraft maintenance error data collection

Research of International aviation literature indicated that the causal factors of 12 to 20% of aviation accidents involved maintenance human factors<sup>27</sup>.

Human factors in maintenance is a topic that many regulatory and other agencies such as the European Aviation Safety Agency (EASA), the International Civil Aviation Organization (ICAO), the Civil Aviation Authority of the United Kingdom (UK CAA), the Australian Civil Aviation Safety Authority (CASA) the Federal Aviation Authority (FAA), Boeing, Airbus and Transport Canada have continued to develop, based on statistical data, in response to continuous improvement concerning the factors affecting human performance.

Similar to EASA proposed changes to Part 145<sup>28</sup>, the *Australian Civil Aviation Safety Regulations (CASR), Part 145*, requires maintenance organisations to apply human factors principles to safety and quality, institute a reporting system with an open and fair reporting culture policy, and ensure that personnel receive training in human factors principles. Training in human factors is required for all employees involved in maintenance, including contracted personnel, similar to the requirements of *CAR-145*.

Maintenance error reporting, and analysis of this data, has been in effect for some time, and listed hereunder are statistics from published data:

1. In 2009<sup>29</sup>, the UK CAA listed the most common maintenance errors found in occurrence reports:
  - a. "Incorrect installation of components
  - b. The fitting of wrong parts
  - c. Electrical wiring discrepancies (including cross connections)

<sup>26</sup> This is part of the State Safety Program in line with ICAO *Annex 19*

<sup>27</sup> Taken from Australia CASA Human Factors resource guide for Engineers:  
[http://www.casa.gov.au/wcmswr/\\_assets/main/lib100215/hf-engineers-res.pdf](http://www.casa.gov.au/wcmswr/_assets/main/lib100215/hf-engineers-res.pdf)

<sup>28</sup> EASA *NPA 2013-01* introduces a new section 145.A.62 internal safety reporting scheme. The overall purpose of the scheme is to use reported information to improve the level of safety performance of the organisation and not to attribute blame.

<sup>29</sup> Reference *UK CAA PAPER 2009/05 Aircraft Maintenance Incident Analysis*.



- d. Loose objects (e.g. tools) left in the aircraft
- e. Inadequate lubrication
- f. Cowlings, access panels and fairings not secured
- g. Fuel/oil caps and refuel panels not secured
- h. Landing gear ground lock pins not removed before departure."

2. In 2008, a National Aeronautical and Space Administration (NASA) study analysed 1062 maintenance incidents reported to NASA's Aviation Safety Reporting System, ASRS,<sup>30</sup>. The most common errors were:

- a. "Required service not performed: (e.g. worn tyres not replaced)
- b. Documentation problems: (e.g. incorrect sign-off)
- c. Wrong part fitted (e.g. -250 tyre fitted to -100 aircraft)
- d. Unapproved or improper repair (e.g. non-compliance with maintenance manual)
- e. Part not installed. (e.g. spacers and washers left off)
- f. Incomplete installation (e.g. nuts left 'finger tight')."

3. UK Data from 2005 to 2011:

In the United Kingdom, EASA Part 145 approved organisations engaged in maintenance of civil air transport aircraft are required<sup>31</sup> to have maintenance error management systems (MEMS), in place as part of the process of obtaining a UK CAA Approval. This is a formal system for investigating serious errors resulting from faulty maintenance in which human factors are a significant element. The objective is to determine the root cause(s) of the error and implement measures to prevent re-occurrence in the future, as far as is practicable.

Confidential Human Factors Incident Reporting Programme (CHIRP)<sup>32</sup>, collects the completed reports from participating UK organisations, de-identifies them and produces a consolidated database for use by participants. In this way, individual organisations can compare their own experiences with the wider UK

<sup>30</sup> ASRS collects voluntarily submitted aviation safety incidents. It identifies system deficiencies, and issues alerting messages to persons in a position to correct them. It educates through its newsletter *CALLBACK*, its journal *ASRS Directline* and through its research studies. Its database is a public repository which serves the FAA and NASA's needs and those of other organizations world-wide which are engaged in research and the promotion of safe flight.

<sup>31</sup> Reference EASA Part-145.A.60 and DIRECTIVE 2003/42/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 June 2003

<sup>32</sup> <http://www.chirp-mems.co.uk/index.asp>. For the complete description of MEMS refer to CAP 716 appendix L on the CAA website and Civil Aircraft Airworthiness Information and Procedures CAP 562 Leaflet B-160 Maintenance Error Management Systems dated October 2012:  
[http://www.caa.co.uk/docs/33/CAP562%20Issue%203%20Amendment%203%2029%20November%202013%20\(complete\).pdf](http://www.caa.co.uk/docs/33/CAP562%20Issue%203%20Amendment%203%2029%20November%202013%20(complete).pdf).



Industry with the objective of reducing the risk of incidents reoccurring as well as reduce the costs associated with maintenance errors. (Figure 8)<sup>33</sup>.

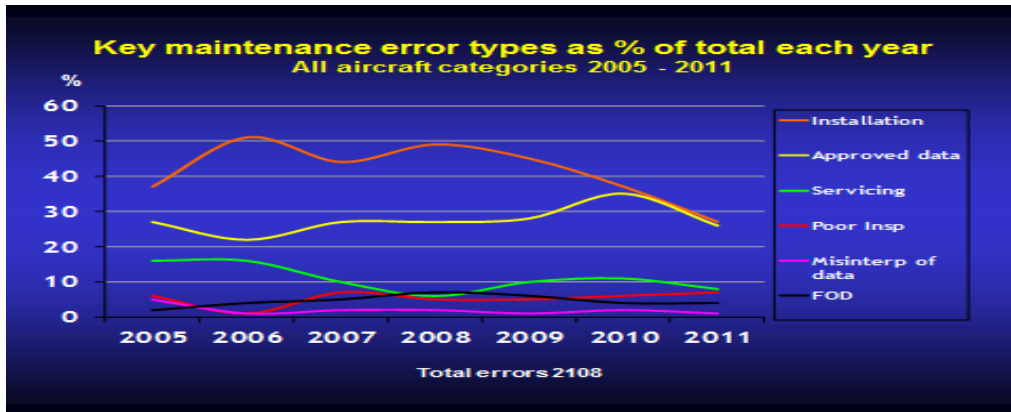


Figure 8. MEMS statistics on maintenance error types

Even though the Operator had MEMS in place, no data or reports were provided to the Investigation. It was noted by that MEMS fell under the responsibility of Quality department.

#### 1.18.9 Examples of Annex 13 historical maintenance errors

Several maintenance errors-related accidents and incidents investigation reports can be found in the investigation literature. The following briefs are relevant to three investigations:

##### 1. The National Transportation Safety Board (NTSB) - Accident report No. NTSB/AAR-13/01

On 7 December 2011, a Eurocopter AS350-B2 helicopter, crashed in mountainous terrain. The pilot and four passengers were killed, and the helicopter was destroyed by impact forces and post impact fire.

The safety issues identified in this accident were:

- “(a) The improper reuse of degraded self-locking nuts.
- (b) Maintenance personnel fatigue
- (c) The need for work cards with delineated steps, and
- (d) The lack of human factors training for maintenance personnel.”

The NTSB made the following three safety recommendations to the Federal Aviation Administration (FAA):

- “(a) (A-13-01) Establish duty-time regulations for maintenance personnel working under 14 Code of Federal Regulations Parts

<sup>33</sup> Table published by Mick Skinner in May 2012 at Dubai addressing A Collaborative Approach to Safety Management.





121, 135, 145, and 91 Subpart K that take into consideration factors such as start time, workload, shift changes, circadian rhythms, adequate rest time, and other factors shown by recent research, scientific evidence, and current industry experience to affect maintenance crew alertness."<sup>34</sup>

"(b) (A-13-02) Encourage operators and manufacturers to develop and implement best practices for conducting maintenance under 14 Code of Federal Regulations Parts 135 and 91 Subpart K, including, but not limited to, the use of work cards for maintenance tasks, especially those involving safety-critical functions, that promote the recording and verification of delineated steps in the task that, if improperly completed, could lead to a loss of control."

"(c) (A-13-03) Require that personnel performing maintenance or inspections under 14 Code of Federal Regulations Parts 121, 135, 145, and 91 Subpart K receive initial and recurrent training on human factors affecting maintenance that includes a review of the causes of human error, including fatigue, its effects on performance, and actions individuals can take to prevent the development of fatigue."

## 2. The UAE GCAA Case file 05/2007<sup>35</sup>.

In April 2007, an Airbus A300-600 was undergoing a heavy check at a UAE maintenance organisation. The aircraft caught fire, which consumed the whole structure.

At the time of the fire, the aircraft was parked in the hangar. One person was injured jumping from door 4R resulting in a fracture of his left leg and hip.

As per the final report, the fire was probably caused by either an electrical spark, or arc from a faulty light, or by an electrostatic discharge from paint spraying equipment while the aircraft was in interior painting works.

The following were determined as contributory factors:

- "(i) The painting process could have generated a layer of flammable vapor close to the cabin floor which may have led to creating flammable vapor pockets under the polythene sheets.
- (ii) The spread of the fire was probably exacerbated by the lack of fire extinguishers and the quantity of used paint cans, rags, polythene sheets and chemicals existent in the aircraft.
- (iii) The non-adherence to the company procedures and standards pertinent to aircraft painting by personnel involved in the aircraft painting works."

<sup>34</sup> Safety Recommendation from the *NTSB A-13-01* Supersedes Safety Recommendation A-97-71 and it was classified a "Open—Unacceptable Response" received from the FAA.

<sup>35</sup> The investigation, reference *report 05/2007*, was conducted by the GCAA being the State of Occurrence.



Fifteen safety recommendations were made pursuant to the investigation.

Three out of the 15 were addressed the maintenance organization:

- "(i) The MRO [maintenance repair organization] shall establish a system to monitor human factor performance for all staff. This should include planning of working hours and shift patterns to insure [ensure] efficiency without inducing great pressure and stress on staff, which may lead to safety hazard.
- (ii) The MRO shall establish systems and processes insuring [ensuring] that the MRO higher management are actively involved in identifying and implementing corrective measures to resolve safety related deficiencies.
- (iii) The MRO shall establish and implement a safety management system, with the objective of minimizing risk, this should include identifying safety hazards and mitigations."

All safety recommendations addressed in the final report were closed with supporting actions by the maintenance organization in 2013.

3. Air Accident Investigation Branch (AAIB) Bulletin 6/2011 Serious Incident, Bombardier DHC-8-102

After a base maintenance check, on 24 April 2010, the aircraft was flown uneventfully to another airport for re-painting works. During the return flight, the right engine suffered a significant oil leak and lost oil pressure, so subsequently the crew shut it down. Shortly thereafter, the crew noticed the left engine also leaking oil, with a fluctuating oil pressure; accordingly they initiated a diversion and performed an uneventful landing. The oil leaks were traced to damaged O-ring seals within the oil cooler fittings on both engines.

The final report stated that both oil coolers had been removed and refitted during the base maintenance check and it was probably during re-installation that the O-ring seals were damaged. A number of factors led to this damage and to skipping oil leak checks.

Six Safety Recommendations were made but only two are mentioned in this Report:

(i) *Safety Recommendation 2011-018*

"It is recommended that the European Aviation Safety Agency [EASA] expand the advisory or guidance material in Annex II (Part 145) of European Commission Regulation (EC) No. 2042/2003 on how approved maintenance organisations should manage and monitor the risk of maintenance engineer fatigue as part of their requirement to take human performance limitations into account."

The response of EASA to that safety recommendation stated, "As part of the implementation of the International Civil Aviation Organisation (ICAO) standards on "Safety Management System" (SMS), maintenance organisations will be required to implement





a system to identify hazards, to assess associated risks and to take appropriate mitigation action (ICAO standard 8.7.3.3 (Annex 6 Part I)). The agency will address the relevant ICAO SMS standards for Regulation (EC) No. 2042/2003 by means of rulemaking task RMT.0251 (former MDM.055). In the framework of this rulemaking task the Agency will identify the need for additional requirements, acceptable means of compliance and guidance material to properly consider human factors in maintenance and continuing airworthiness management. Maintenance staff fatigue will be addressed as part of this review.”

As per EASA website, under 2012 Annual Safety Recommendations Review, the status of SR 2011-018 was considered 'closed' and categorized as in Agreement. As a result, NPA 2013-01A/B/C<sup>36</sup> was issued by EASA as mentioned in rule making task RMT.0251 for comments by the aviation industry.

"(ii) *Safety Recommendation 2011-019*

“It is recommended that the Civil Aviation Authority [UK CAA] include the following areas in their Part-145 audits: practices and procedures for detailing repair instructions, identification of safety critical tasks, planning of defect rectification and management of maintenance engineer fatigue.”

The UK CAA accepted this safety recommendation and responded “that it has enhanced its oversight on the maintenance organisations, with particular focus on their practices and procedures for detailing repair instructions, identification of safety critical tasks and planning of defect rectification. A series of audits and product samples have been carried out to verify the adequacy of the maintenance organisations' procedures. This oversight will continue to be applied as the maintenance organisation continues its on-going review and refinement of the task management process.”

The UK CAA added in its response, "In the absence of a requirement for AMOs [approved maintenance organisations] to manage maintenance engineer fatigue and pending any formal expansion of advisory and guidance material from EASA in Part-145 to explain how this should be accomplished (in response to Safety Recommendation 2011-018), the CAA will monitor the organisation's response to issues relating to shift working and potential impact on engineering staff through its audit of the operators' production and manpower planning processes."

The UK AAIB accepted the UK CAA response and closed the safety recommendation.

<sup>36</sup> NPA 2013-01 is in three parts, A, B and C, and addresses Embodiment of Safety Management System (SMS) requirements into *Commission Regulation (EC) No 2042/2003*. Part A gives Explanatory Note and executive brief, Part B addresses Part-M organizations and Part C addresses Part-145 organizations.



#### 1.18.10 Information on aircraft maintenance personnel duty times

A review based on staff involvement in safety sensitive aircraft maintenance activities was conducted by the Investigation to determine what regulations or guidelines were available within the UAE and Internationally. Reference was made to the the number of consecutive working days, official weekly off-duty days, maximum working hours per day, minimum rest period between shifts, staff working night shift and fatigue risk management system.

##### 1.18.10.1 The United Arab Emirates *Labor Law*

The following is an extract from the UAE *Labor Law*<sup>37</sup>:

Article 65 states, "The maximum normal working hours for adult employees is 8 hours per day or 48 hours per week. In case of commercial establishments, hotels, restaurants, watchmen and other similar professions, this period may be extended to nine hours a day by a decision of the Minister of Labour. The normal working hours will be reduced by two hours during the holy month of Ramadan."

Article 66 states, "The daily working hours shall be so regulated that no worker shall work for more than five successive hours without breaks - for rest, meals and prayer- amounting in aggregate to not less than one hour. Such breaks shall not be included as part of the working hours."

Article 67 states, " If the nature of job demands employing workers beyond normal working hours, the additional time will be considered overtime and will entitle the employee for remuneration corresponding to normal working hours, plus an additional pay of not less than 25% of the remuneration."

Article 68 states, "If circumstances require that an employee works overtime between 9 PM and 4 AM, he shall be entitled for remuneration of regular working hours pay, plus an increase of not less than 50% of that amount."

Article 70 states, "Friday is the weekly holiday for all employees except for daily wage workers. If circumstances require that an employee works on this day, he shall be entitled for another day off or paid his basic pay for normal working hours plus an increase of not less than 50% of that pay."

##### 1.18.10.2 UAE *CARs*

The Regulations do not specify working hours or duty time limits for personnel involved with aircraft maintenance or safety sensitive work. Some of the relevant sections on production planning involving human factors can be found in *CAR* under section 145.67<sup>38</sup>.

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<sup>37</sup> The official version of the UAE *Labor Law* is in Arabic and should be referred to for clarification. "The Federal Law No. (8) of 1980, or the UAE Labour Law, is a comprehensive law that regulates all aspects of labour relations between employers and employees. It is an advanced and balanced law that clarifies the rights and duties of all parties concerned and brings numerous benefits to employees and workers. The Labour Law was developed in 1980 and was amended by Federal Law No. (24) of 1981, Federal Law No. (15) Of 1985 and Federal Law No. (12) Of 1986. In its article 193, the law outlines everything from employees' entitlements (working hours, holidays, leaves, end of service gratuity, workers' compensation, etc.) to employment contracts, labour dispute settlement, disciplinary rules, safety and protection and labour inspection, among others.

<sup>38</sup> See [Appendix](#) of this Report for the relevant section of *CAR* 145.67



There are varying duty times for aviation organizations within the UAE. It was noted, based on GCAA Audits that some companies did have audit findings related to duty times. This ranged from employees in safety sensitive jobs working more than 12 hours a day, some working in excess of 60 hours a week and some working long periods beyond 7 days without a day off.

The Investigation could not determine what scientific approach or best industry practise was being applied for shift rosters and duty times at the Operator.

#### 1.18.10.3 United Kingdom Civil Aviation Authority (UK CAA)

The UK CAA has published guidance material for EASA approved Part-145 organizations on human factors and error management requirements. This guidance material is under *Civil Aviation Publication (CAP) 716*<sup>39</sup> – *Aviation Maintenance Human Factors*, and was first published in January 2002. Reference is also made to documents and studies performed by other authors on aviation safety in aircraft maintenance including studies funded by the FAA<sup>40</sup>.

*CAP 716* provides guidance material for maintenance organisations in order to reduce the risks associated with human error and human factors, and improve safety.

Before *CAP 716*, there were no duty time limitations for aircraft maintenance personnel and the only requirement relating to fatigue being that the requirement for aircraft maintenance planners to take into account human performance and limitations (*Part-145.A.47(b)*).

However, the national UK legislation does address duty time and was initially mandated based upon the *EC Working Time Directive 93/104/EC* dated 23 November 1993. As stated; “The aim and rationale behind the EU Directive, and its UK national implementation, is to protect individuals rather than to ensure aviation safety, nevertheless appropriate implementation of this requirement should mean that individuals do not work excessively long hours, which may jeopardise aviation safety.”

Prior to 2003, the *UK Working Time Regulations*<sup>41</sup> implementation of the European Working Time Directive meant that certain sectors were originally excluded from the scope of the Regulations. However, from 1 August 2003, the regulations were extended to previously excluded sectors, including aviation maintenance personnel.

#### 1.18.10.4 EASA– Notice of Proposed Amendment (NPA) 2013-1- Safety Management Systems for Maintenance Organizations

EASA published an *NPA* on 21 January 2013 (*EASA NPA 2013-1*), Safety Management Systems for Maintenance Organizations, and was communicated with the industry for the comments which closed in May 2013<sup>42</sup>.

<sup>39</sup> Published by the UK CAA Safety Regulation Group. The current edition is August 2006 and can be found on the web site [www.caa.co.uk](http://www.caa.co.uk). See the [Appendix](#) of this Report for the relevant section of *CAP 716*

<sup>40</sup> Reference [www.hfskyway.faa.gov](http://www.hfskyway.faa.gov).

<sup>41</sup> The following information has been extracted directly from the Guidance on the Department of Trade and Industry (DTI) website: [www.dti.gov.uk/er/work\\_time\\_regs/index.htm](http://www.dti.gov.uk/er/work_time_regs/index.htm)

<sup>42</sup> Comments can be found at [hub.easa.europa.eu](http://hub.easa.europa.eu) in the Comment-Response Document (CRD) once it is published.



The three-part document addresses all aspects of maintenance SMS for operators and regulatory authorities. EASA clarifies the rationale for the proposed SMS rules and the impact of the rules for maintenance organizations.

In the *'Executive Summary' of NPA 2013-1*, EASA stresses that the primary goal of the proposed changes is to ensure adherence to the international SMS framework established by ICAO *Annex 19*. That includes review and modifications to EASA's current guidance on human factors. EASA says that the proposed changes strive to be flexible and can be proportioned to the size of the organization. In addition, EASA next phase are plans to issue another NPA for Part 66- *'Personnel Certification'* and Part 147- *'Training Organizations'*.

Mention is made in the NPA that the proposed changes under AMC2 145.A.47(b) Production Planning, instructions is given for Duty Time Schedule and aligns with EU Working Time Directive 2003/88/EC and states:

“(a) The duty time schedule should address, at a minimum, the following topics:

- (1) Maximum scheduled hours/day
- (2) Maximum hours with overtime
- (3) Maximum hours/month
- (4) Minimum rest between shifts (based on shift length)
- (5) Minimum uninterrupted rest hours per week.

All of the above must consider time of day work shift.

(b) Reasonable work hour limits should not be exceeded merely for management convenience even when staff is willing to work extended hours. When maximum work hours are exceeded, the organisation and the individual staff member should have a written plan on how the fatigue risk will be mitigated. This may include:

- (1) Additional supervision and independent inspection
- (2) Limitation of tasks to non-safety critical
- (3) Use of additional rest breaks
- (4) Permission to nap in accordance with guidelines approved by the organisation."

#### **1.18.10.5 European Union, EU, Working Time Directive 2003/88/EC**

As mentioned in the narrative of the document, the main objective of the Directive is to protect workers against excessive working hours and neglect of rest periods.

To protect workers' health and safety, working hours must meet minimum standards applicable throughout the EU.



The following is a summary from EU's 'Working Time Directive (2003/88/EC)'<sup>43</sup> that requires EU countries to guarantee the following rights for all workers:

1. "A limit to weekly working hours, which must not exceed 48 hours on average, including any overtime.
2. A minimum daily rest period of 11 consecutive hours in every 24.
3. A rest break during working hours if the worker is on duty for longer than 6 hours.
4. A minimum weekly rest period of 24 uninterrupted hours for each 7-day period, in addition to the 11 hours' daily rest.
5. Paid annual leave of at least 4 weeks per year.
6. Extra protection for night work, e.g.
  - (a) Average working hours must not exceed 8 hours per 24-hour period,
  - (b) Night workers must not perform heavy or dangerous work for longer than 8 hours in any 24-hour period,
  - (c) Night workers have the right to free health assessments and, under certain circumstances, to transfer to day work."

#### 1.18.10.6 USA- Code of Federal Regulations (CFR) Part 121

In the USA<sup>44</sup>, the hours of service (HOS) limit currently applying to aviation maintenance is Title 14 of the *Code of Federal Regulations (CFR) Part 121, 121.121.377*. It requires that a person performing maintenance be relieved off-duty for at least 24 hours in any seven consecutive days or the equivalent within a calendar month. In effect, a person could work up to 52 days straight, in a period of two consecutive months, and still be in compliance with the regulation.

However, the FAR applies only to personnel maintaining aircraft operated by part 121- *Air Carriers*. As part of its international assistance activities, the FAA formerly provided overseas regulators with model rest and duty limitations for maintenance personnel. These included a 12-hour limit on HOS, extendable to 16 hours in the case of unscheduled maintenance.

It is uncertain whether the FAA will propose HOS regulations at some future time.

<sup>43</sup> As of March 2014, EU working time directive was under review referenced "Second-phase" consultation of the social partners at European level under Article 154 TFEU.

<sup>44</sup> Researched data taken from [www.faa.gov/library/reports/medical/oamtechreports](http://www.faa.gov/library/reports/medical/oamtechreports) under DOT/FAA/AM-11/10 Fatigue Risk Management in Aviation Maintenance: Current Best Practices and Potential Future Countermeasures written by Hobbs A, Avers KB, Hiles JJ, published June 2011.



#### 1.18.10.7 New Zealand Civil Aviation Authority Rule, Part 43.53

The New Zealand CAA Rule Part 43.63 requires that before performing work, maintenance personnel must have had at least eight hours off-duty in the preceding 24 hours and at least four periods of 24 consecutive hours of break in the preceding month.

#### 1.18.10.8 Civil Aviation Administration of China (CAAC)

The Civil Aviation Administration of China, CAAC, specifies a maximum duty time for aviation maintenance personnel of eight hours per day, with a maximum of 40 hours per week. Extended duty is permitted under special circumstances, up to a total of 11 hours per day. However, total monthly overtime is limited to 36 hours per month.

#### 1.18.10.9 Australia, Civil Aviation Safety Authority (CASA)

The Australia Civil Aviation Safety Authority, CASA, under *Civil Aviation Safety Regulations (CASR)*, MOS AMC 145.A.65 (b) 1,6- *Fatigue and Impairment Management* gives the requirements for an AMO to ensure that any employee capacity to perform maintenance is not significantly impaired as summarized:

- a. "No scheduled shift should exceed 12 hours.
- b. No shift should be extended beyond a total of 13 hours by overtime.
- c. A minimum rest period of 11 hours should be allowed between the end of shift and the beginning of the next, and this should not be compromised by overtime.
- d. A maximum of four hours' work before a break.
- e. A minimum break period of ten minutes plus five minutes for each hour worked since the start of the work period or the last break.
- f. Scheduled work hours should not exceed 48 hours in any period of seven successive days.
- g. Total work; including overtime, should not exceed 60 hours or seven successive work days before a period of rest days.
- h. A period of rest days should include a minimum of two successive rest days continuous with the 11 hours off between shifts (i.e. a minimum of 59 hours off). This limit should not be compromised by overtime."

#### 1.18.11 Fatigue and fatigue risk management systems (FRMS)

Research data on the effects of fatigue<sup>45</sup> management involving aircraft maintenance personnel has been funded and conducted by many States. Listed

<sup>45</sup> As mentioned in CAR-OPS 1- "Fatigue is- A physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member's alertness and ability to safely operate an aircraft or perform safety-related duties."





hereunder, are some of the world aviation authorities implementation plans for FRMS<sup>46</sup> including mention of the GCAA:

#### 1.18.11.1 GCAA on FRMS for Part-145 Organizations

Regulations for flight crew and cabin crew members is detailed in *CAR-OPS 1* and *CAR-OPS 3*, however a review of the UAE regulations pertaining to Part-145 and CAR-145 approved organizations; the GCAA does not specify that certificate holders performing aircraft maintenance must employ any FRMS system or duty time limits. In addition, there are no specific instructions or guidelines that can be referred to by a GCAA certificate holder who wishes to implement an FRMS system.

#### 1.18.11.2 EASA NPA 2013-1 AMC1 145- Fatigue Risk Management

As a result of *Annex 13* Investigations, and safety recommendations addressed to EASA, *NPA 2013-1* was issued in order to augment effective safety management in the area of continuing airworthiness management due to the potential for maintenance errors and more specifically the impact of maintenance personnel fatigue.

The two safety recommendations mentioned in *NPA 2013-1* are:

"(a) SR following a serious incident to Bombardier DHC-8, occurred on 24 April 2010: 'It is recommended that the European Aviation Safety Agency expand the advisory or guidance material in Annex II (Part 145) of European Commission Regulation (EC) No 2042/2003 on how approved maintenance organisations should manage and monitor the risk of maintenance engineer fatigue as part of their requirement to take human performance limitations into account.'

(b) SR following a serious incident to Boeing 737-73V, occurred on 12 January 2009: 'It is recommended that the European Aviation Safety Agency review the regulations and guidance in OPS-1, Part-M and Part-145 to ensure they adequately address complex, multi-tier, sub-contract maintenance and operational arrangements. The need for assessment of the overall organisational structure, interfaces, procedures, roles, responsibilities and qualifications/competency of key personnel across all subcontract levels within such arrangements should be highlighted.'

The proposed changes, stated in *NPA 2013-1* section *AMC1- 145.A.46 (b)- Production Planning Fatigue Risk Management* are quite detailed and addresses the hazard associated with fatigue. More details can be found in the Appendix of this Report.

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<sup>46</sup> As mentioned in *CAR-OPS 1*- "FRMS is- A data-driven means of continuously monitoring and managing fatigue-related safety risks, based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness."



#### 1.18.11.3 The Federal Aviation Administration (FAA)

The FAA<sup>47</sup> has issued many related videos and documents related to fatigue and how to manage same. Even though fatigue for aircraft maintenance personnel is not regulated within the USA, the FAA has performed many studies and has shared this information with the aviation community.

#### 1.18.11.4 Transport Canada- Fatigue Risk Management

Transport Canada (TC)<sup>48</sup> has been one of the world aviation authorities' leaders with fatigue risk management system and has published detailed information that can assist organizations in setting up an FRMS system.

With reference to TC FRMS document *TP14575E- Developing and Implementing a Fatigue Risk Management System*- The fatigue risk management system described in this guide provides companies and employees with a recognized process based on likelihood and consequence and the need to identify, understand, and control the workplace hazard. The resources and time required for implementing a fatigue risk management system will be determined by the relative risk identified during the risk assessment process.

#### 1.18.11.5 Australia, Civil Aviation Safety Authority (CASA)

The Australia Civil Aviation Safety Authority, CASA, under *Civil Aviation Safety Regulations (CASR), MOS AMC 145.A.65 (b) 1,6- Fatigue and Impairment Management*<sup>49</sup> gives guidance to the Australian aviation industry in establishing a system so as to ensure that any employee capacity to perform maintenance is not significantly impaired.

### 1.19 Useful or effective investigation techniques

No new investigation techniques were used during this Investigation.

<sup>47</sup> The FAA has several guidelines, tips and posters on ways to minimize errors as a result of fatigue and can be found [http://www.faa.gov/about/initiatives/maintenance\\_hf/fatigue/multimedia/](http://www.faa.gov/about/initiatives/maintenance_hf/fatigue/multimedia/) And [http://www.faa.gov/about/initiatives/maintenance\\_hf/fatigue/publications/](http://www.faa.gov/about/initiatives/maintenance_hf/fatigue/publications/)

<sup>48</sup> Transport Canada has published many topics on FRMS and can be found under "Fatigue Risk Management System for Canadian Aviation - FRMS Toolbox" <https://www.tc.gc.ca/eng/civilaviation/standards/sms-frms-menu-634.htm>.

<sup>49</sup> See [Appendix](#) of this Report for a summary of Australia CASA regulations *MOS AMC 145.A.65 (b) 1,6*



## 2. Analysis

### 2.1 General

Based on the factual information, the Analysis will mainly examine the events that influenced this maintenance error. The handling of the Incident flight by the flight crew is not of significance to this Investigation, as standard operation procedures were followed.

Besides flight crew, the unregulated duty times and risk associated with fatigue for all workers involved with an aircraft operation requires attention from the GCAA.

Factors taken into consideration in this Investigation, and discussed in the analysis, involve elements that the human being is exposed to, especially in a production environment.

Together with company procedures, authority regulations and including aircraft system testing, inspections and certification, it would be expected that any maintenance error should be easily identified and corrected before an aircraft is released for flight. However, errors continue to happen in spite of the safety nets in place.

The mistake of a person at the control of a safety related aircraft maintenance activity can have very serious consequences. As maintenance work must be performed by a person, the onus and overall responsibility of the organization in support of this person is sometimes influenced by financial targets, and operationally related requirements.

Similar to the flight crew, the position of the maintenance person is critical to the safe release and operation of an aircraft. The maintenance person should not feel alone in making a decision that may negatively affect the company.

Many organizations, through human factors training, share lessons learned from internal reports of hazards and errors. An indicator for how effective a safety culture is within a company is the investigation philosophy used and the treatment of people who made errors leading to incidents.

In many occasions, internal investigations are performed where the focus of the investigation is confined to the person performing the task as the only element investigated. Provided the incident did not result from a willful act, the investigation as to why a person made a mistake should not be confined to that person only. No error occurs in isolation as there will be other factors that would have contributed to, and influenced, the error. If the investigation does not encompass other possible contributing factors then, it is most likely, that error will reoccur.

A just culture within an organization provides its employees with a reporting mechanism whereby they feel encouraged to report hazards, maintenance errors, factors affecting performance, and any unsafe act. The company should encourage and recognize the honesty of the person reporting without that person feeling any apprehension. The benefits of this approach add value to the company and improve safety performance.

As companies embrace SMS, a more proactive approach should be implemented which can and will bring an overall improvement to safety. However, the



approach towards continued improvement requires the valuable contribution of all concerned within the organization and starts from the top. Companies have come to realize that by improving safety, the image of an airline is appreciated and valued due to its impeccable safety record.

## **2.2 The Operator**

### **2.2.1 The Incident flight**

The flight crew and passenger preparation for the early morning flight was normal and proceeded without any irregularities. This was the first flight of the day, however, as no log book entry had been made by the Engineer, the flight crew were unaware that the Aircraft had undergone engine washes during the night stop, and that the first engine start was, in fact, a verification of the maintenance work performed during the engine washes.

The passenger who witnessed and reported this Incident to the crew, stated that it was difficult to hear the pre-flight safety announcement, due to the noise of the engines and propellers.

As there were no cockpit warning indications during engine start, taxi and the initial flight phase to indicate any abnormal situation, the flight crew were unaware that both engines were operating with one igniter not installed on each engine.

The gradual change in the paint color, the paint blistering of the right engine nacelle panel, and the potential effect to the continued safe operation of the aircraft was not a situation that the CCM had experienced before, nor was it part of the cabin crew CRM training. His interaction with the passenger was not conclusive as the CCM was not technically prepared for such situations. Had the flight crew workload increased due to engine warnings, or any Aircraft system degradation, the critical phase when the CCM entered the cockpit, less than a minute after takeoff, could have impacted on the performance of the flight crew. From the information given to the flight crew by the CCM, verification was done by the co-pilot to enable them to have a clear understanding and aid their decision making process.

The flight crew discussed during the interviews that the sight of exhaust gases emitting from the engine vents is not unusual and they have had similar passenger concerns previously. Their initial assumption was based on this knowledge.

The decision to return to the departure airport was made after the co-pilot had heeded the persistent request of the concerned passenger which was made known to the flight crew by the CCM.

### **2.2.1 DHC-8-315 Engine Washes**

The Operator's aircraft maintenance supervisors, during the interviews, had mentioned that they had used their experience on this aircraft type, DHC-8-315Q, in concluding that the engines were being removed prematurely due to on-wing performance degradation. As they explained, this was mainly due to the environmental conditions existing in the areas of operation of the Aircraft. Collectively, they decided that the company would benefit if an additional engine compressor wash was performed. There was no evidence that their decision was discussed with management nor was there any change to procedures.



As the scheduled maintenance program in place prior to the Incident flight of 09 September 2012 mainly concentrated on the turbine section of the engines, the supervisors introduced an additional engine compressor desalination water wash that was to be carried out together with the already existing turbine wash. They thought that it was best to conduct this additional wash on one specific engine as a trial since no historical data was available as to any potential benefits of the additional wash.

The engine selected for the trial was installed on the Incident Aircraft on 11 July 2012 in the LH position. However, when the actual washes started, the work was being performed based on experience alone, and without any referral documentation from the AMM to perform the physical task. In addition, the work was being conducted without any sign-off by the mechanic, or the engineer, and without any updates being entered into the electronic data system of the Operator.

The dissemination of information by the supervisors to other team members for this newly introduced engine wash was performed verbally.

From the interviews conducted with the mechanics, it was apparent that the information being communicated on each occasion was not the same as there were different understandings as to what was actually required to be performed, and on which aircraft.

On the night prior to the Incident flight, the duty Engineer in charge of the shift had physically prepared both engines for turbine washes, as per the planned work referenced in document *EGEN F/W 11*<sup>50</sup>. He removed engine access panels 415AL and 425AL, the igniter leads and the left igniter from each engine. The right igniters were not removed as they were not required to be removed for the turbine wash.

The removed igniters were left inside the recess of the engine compartment without placing them in protective bags.

After rectification of the NLG defect, the Engineer instructed that the Aircraft be towed out of the hangar to the designated wash bay area as the aircraft required an external wash. Before towing, the engine panels 415AL and 425AL that had been opened to allow the removal of the igniters, were both closed.

However, no external tell-tale indicator, such as a streamer, was used to indicate that items had been removed and left inside the compartment.

The Aircraft was towed outside the hangar and the Engineer returned to the control room where he proceeded to update the electronic data system.

Two mechanics, who were assigned to another aircraft, returned to the control room, as they had completed their assigned tasks. The Engineer then requested both of them to perform the engine washes on the Aircraft. This instruction was verbal, without specifying what engine wash was required, and the Engineer did not mention that the engines had already been prepared for the turbine washes.

The mechanics were experienced in performing turbine washes, but they were not authorized by the Operator's Quality Director to perform unsupervised engine motoring. They were aware that this Aircraft had a special requirement related to compressor washes. However, as mentioned during the interviews, they were not sure

<sup>50</sup> See [Appendix](#) of this Report for *EGEN F/W 11*.



whether or not the turbine washes also had to be performed on the Aircraft, and they concluded that only the compressor washes were required.

The mechanics removed panels 413AL for the LH engine and 423AL for the RH engine, in order to access the compressor plugs. The single access plug (figure 5) on the external engine compressor casing was then removed.

The compressor washes do not require panels 415AL and 425AL to be opened.

After the engine washes were completed, both engine compressor plugs and access panels were normalized. At no time during this wash sequence was any aircraft manual referred to, nor was any attempt made to access the turbine section in order to perform the turbine water washes.

Both mechanics returned to the control office around 1 hour before the end of shift and verbally informed the Engineer that the engine washes were completed. The assumption made by the Engineer was that the mechanics were referring to the completion of the turbine washes. He was unaware that the mechanics had actually performed compressor washes on both engines, and had not performed the planned turbine washes.

The Engineer, as he was dealing with other documentation in the control office, was not involved with the engine washes nor did he physically verify that the engine igniters were normalized after the washes before signing off the work in the Aircraft maintenance log book.

The reason for the Engineer's decision not to inspect the Aircraft is unknown. However, his decision making process may have been influenced by the closeness of the time to the end of the shift, his confidence in the mechanics, the practice of allowing mechanics to perform the engine washes, cumulative fatigue due to the number of days on continuous duty, as well as the fact that on the day before he had worked overtime of about 3.5 hours. His duties as a supervisor in electronically entering data could also have influenced his decision.

At the end of the shift that evening, the Engineer noted in the hand over log that the engine washes were completed, and the Aircraft was airworthy for flight.

### 2.2.3 Production and documentation control

Prior to December 2011, the Operator had a reference document, A7200/01<sup>51</sup> dated May 2009, for the turbine water washes. As this task was being performed on every night stop, or every 24 hours of aircraft operation, and on both engines of the Operator's fleet of DHC8, there was a request from the maintenance staff to have a reduction in the related paperwork.

Thus, in order to improve process efficiency, and with the approval of the Operators Quality Director, the paperwork was removed in December 2011. This was replaced with *Procedure Number EGEN F/W 11*<sup>52</sup> that required a stamp in the aircraft maintenance log book which was then certified by an authorized engineer. It was noted that the mechanics did not sign-off for this work, and instead confirmation that the wash had been completed was verbally communicated to the engineer.

<sup>51</sup> See Appendix of this Report for A7200/01.

<sup>52</sup> See Appendix of this Report for EGEN F/W 11.





In summarizing *CAR 145.47*, the Operator is required to implement best practices for conducting maintenance but not limited to, the use of work cards for maintenance tasks, especially those involving safety-critical functions that promote the recording and verification of delineated steps in the task that, if improperly completed, could lead to a loss of control.

Similar to other examples of Annex 13 investigations mentioned in this Report, the Operator did not provide an approved maintenance task card for the Engineer nor the mechanics to perform the safe completion of the engine washes. This contributed to the reason why the igniters were not refitted prior to flight. In addition, as a result of a lack of production control personnel, the Engineer had the responsibilities of data entry together with manpower allocation and supervision.

#### **2.2.4 The Operator's safety culture**

From the Investigation, it was noted that the maintenance staff attended monthly meetings but as these were not always documented with the actual subject matter, the effectiveness of this meeting was unknown. The meeting, also attended by Management, would have been a good indicator as to how staff related to safety within the company. It is not known as to whether or not the engine washes were discussed, but the fact that work was been performed, without being recorded and certified, should have raised concerns amongst the aircraft maintenance personnel. This reflects the point that the staff believed that what they were doing was right, and probably indicates that it was an accepted practice.

For any operator, safety defences are put in place to capture, or at least minimize, maintenance errors. The Investigation found that even though the Operator had safety measures in place, those safety defences failed as they were overlooked or not followed, allowing the aircraft to be released to service in an unsafe and un-airworthy condition.

The following analysis is based on evidence provided prior to the Incident in September 2012:

- For the 2008/2009 head count reduction, management of change risk analysis and the introduction of safety measures to mitigate any risk was either not done, or not provided to the Investigation.
- The introduction of SMS regulations by GCAA in 2011 required that all Operators' management and employees be appropriately trained on SMS. This was not conducted until 2013 as evidenced by the numerous audit findings recorded by the GCAA.
- GCAA audit findings between 2009 and 2012 revealed that safety management and implementation was of concern, as the same issues were repeated over several audits (Reference section 1.18.6). However, following the appointment of the safety postholder, a comprehensive SMS Implementation Plan was submitted to the GCAA in November 2012 and later approved the Plan in January 2013.
- Safety reports submitted to the GCAA ROSI system in accordance with *GCAA CAAP 22* by the Operator numbered 14 over a 3 year period and may have indicated a lack of understanding of what should be reported. However, after the introduction of a new web-based SMS in mid-2012 and



the internal transfer of the ROSI submission process from Quality to Safety in early 2013, the number of ROSI reports submitted to the Authority increased considerably.

- The Operator's SMS section was understaffed and a request was made to assign additional staff at the time of the Incident in September 2012. An additional employee subsequently joined the Safety Department in January 2014.
- The internal safety reporting program of SMS was in place and did highlight some safety issues reported by maintenance staff. However, safety hazards highlighted in this investigation were not reported. This may indicate a deficient safety reporting culture.
- It was noted by that MEMS fell under the responsibility of Quality department.
- The supervisors' discussion, and their final decision to implement the engine compressor wash during the night stops, was based on assumptions and not on factual information. Their decision was driven by the need to extend the on-wing life of the engines. Such a decision should have come from the Operator's engineering department responsible for engine performance monitoring, based on factual engine monitoring data.
- Thereafter, their actions of not requesting the planning department to issue a controlled document for the engine compressor wash and not informing the Engineering Director, may indicate communication apprehension related to their actions.
- The engine washes started in July 2012, yet there is no evidence that the Quality Department conducted an effective audit of aircraft maintenance activities and documentation from July 2012 until the occurrence of the Incident in September 2012. These audits are a requirement of *CAR-145*. An audit would, most likely, have detected that unrecorded work was been performed on the aircraft.
- The decision by the Quality Director to accept removal of the planning document *A7200/01*, which required sign-off by the mechanics, as well as certification by the engineer. Documentation may be a burden for the certifying staff, but is one safety defence that if removed, increases the chances of not capturing an error.
- The new procedure introduced by the Engineering Director and approved by the Quality Director, for the turbine washes with only a stamp in the aircraft maintenance log requiring the engineer to signoff. This had no reference paperwork, nor did it have any mechanic signoff. This allowed mechanics to perform work on the aircraft, and then verbally communicate to the engineer that the work was completed.
- The practice of performing unrecorded work on an aircraft.
- On the night prior to the Incident flight, the Engineer had to continue working on the aircraft beyond his normal duty finishing time of 2200 LT, due to operational requirements. He eventually left work at 0130 LT on 08



September. He reported again for duty at 1330 LT for his afternoon shift of the same day. It is not unusual to work overtime in aviation, but as the Operator had no means of verifying staff fitness for work, and especially detecting fatigue, the Engineer was probably affected in his decision making process due to physical tiredness, as a result of the shift roster.

- The Engineer would have also been affected in his ability to be assertive as a certifying engineer due to the company allowing unsupervised work, his responsibilities for entering data in the Operator's electronic system, and his assumption that the mechanics were familiar with the engine wash procedure.
- The Operator's mechanics performing engine washes without supervision. This was a practice which was not highlighted as a safety concern by the Quality department.
- The Operator did not identify the removal of engine igniters as a critical task, which should have required a duplicate inspection.
- The Operator allowing the normalizing of the engine ignition system after engine washes, without performing a test of the system.
- The practice of not attaching a telltale streamer for parts that have been removed from a hidden location. In addition, not putting warning tags in the cockpit indicating that an aircraft system was disturbed.
- The Operator allowing engine washes to be performed without engine runs being carried out by the engineer after the wash, provided that the next flight was within 12 hours of the engine wash. This engine run was allowed to be done by the flight crew, but there was no entry made into the aircraft log book to alert the flight crew that an engine wash was performed and that the engine run was verification for the maintenance action.

Human factors training, together with SMS awareness, should have reminded the supervisors, engineers, and mechanics that the work they were performing on the Aircraft, namely compressor engine washes, and not recording this work, would have eventually led to consequential effects. Yet, they continued this practice for two months until the Incident flight.

The Operator did provide structured human factors training, which was attended by all aircraft maintenance personnel. In spite of this training, this Incident involving omission of installation of a critical part was an error waiting to happen from the inception of the uncontrolled engine washes that started in July 2012.

Organizational structure of the company in support of a person, especially those who provide a final signature for aircraft release, should always be of great importance. This includes but is not limited to training, coaching, resource planning, maintenance task planning, available tooling, logistic support, referenced aircraft manuals and documentation, environmental control, management positive support, sufficient rest period, fatigue and stress management and supporting open discussions and reporting affecting safety.

The aviation industry would normally implement additional safety measures based on errors, risk assessment, performance indicators, and employee feedback as well as from surveys similar to safety culture surveys.



Besides what has been stated in the analysis, the Investigation could not determine any safety trend from the Operator's aircraft maintenance personnel as no safety culture survey had been performed. Even though it is not the only tool to assess safety culture, a safety survey can assist in improving SMS based on employee feedback.

### 2.2.5 Duty timings

As the Operator's main business was in support of the oil industry, the shift rostering for most of the aircraft maintenance personnel who were stationed at the main maintenance facility had a work pattern of 56 days on-duty followed by 28 days off-duty. During the interviews, the staff mentioned that they were pleased with the shift as after every two months on-duty they would be flown to their home country allowing them to be with their families as many of them lived alone.

However, they did mention that being on-duty for consecutive days without a day off, even with the average working hours per day of 8.5 hours including 1 hour break, did affect their performance. The Investigation could not scientifically substantiate their statements, but they mentioned that after about 2 weeks on continuous duty, they felt tired and fatigued, which affected their ability to perform their work diligently.

Table 6 illustrates the on- and off-duty days for the five maintenance personnel who worked on the Aircraft. The shift timings include a 1 hour break.

<b>Table 6. On-Duty maintenance staff roster</b>			
Shift: E: 0600 to 1430 L: 1330 to 2200	On-Duty days till 8 September 2012	Total hours on-duty @ 8.5hrs/day	Off-Duty days rostered prior to 8 September 2012
The Incident Engineer	32	272	2
Engineer	3	25.5	Resumed duty on 6 September 2012
Mechanic 1	21	178.5	1
Mechanic 2	32	272	2
Mechanic 3	2	17	Resumed duty on 7 September 2012

Based on this evidence, it is not confirmed to what extent the accumulated fatigue would have influenced the maintenance error.

Research has shown that lack of sleep can have negative effect on the ability of a person to perform some tasks, especially safety sensitive tasks. Evidence exists that states; "A 2-hour sleep debt can produce performance decrements comparable to those produced by a blood alcohol level of 0.045 percent and that a 4-hour sleep debt can produce performance decrements comparable to a blood alcohol level of 0.095 percent<sup>53</sup>."

<sup>53</sup> For more information, see T. Roehrs, E. Burduvali, A. Bonahoom, et al., "Ethanol and Sleep Loss: A 'Dose' Comparison of Impairing Effects," *Sleep* 26, no. 8 (2003): 981-985.



Based on the GCAA Regulations, there is no requirement for an Operator to have any particular shift roster for staff involved in safety sensitive tasks. The roster developed by the Operator was implemented to meet their operational requirements.

### 2.3 Duty Times- Aircraft Maintenance Personnel

From the Operator's data, 87% of fixed-wing aircraft maintenance personnel worked on a shift basis with approximately 80% of them working an average of 8.5 hours a day on a shift pattern of 56 days on-duty followed by 28 days off-duty. None of the staff that worked on the Aircraft had reported any performance degradation on that shift. There was no evidence of a reporting method or system to allow maintenance personnel to report if they feel unfit to work due to fatigue and what company procedures are to be followed in such a case.

Companies are probably meeting the minimum requirements but without having a structured and regulated approach which includes a fatigue risk management system, FRMS, allows for diversity from company to company with the working hours of its employees. Implementation of Civil Regulations should be able to reduce the risk associated with working unregulated hours as data has shown that companies within the UAE are allowing workers to be on duty in excess of 12 hours a day, or more than 60 hours over a 7 day period or continuous days on duty without a day off.

The unregulated hours and frequent night work characteristic of maintenance can produce significant levels of fatigue, with a resultant risk of maintenance error.

In the Australian CASA research of maintenance errors, it has been estimated that, all other factors being equal, the risk on a 12-hour shift system is some 27.6% higher than that on an 8-hour system. Shifts longer than 12-hours should thus clearly be considered as undesirable. For the same reason, it would seem wise to limit the extent to which a shift can be lengthened by overtime so as to eliminate the associated risk.

UK CAA in year 2003 published the *Civil Aviation Publication CAP 716*, which was based on detailed study of the effect of working hours. This publication has been used as a benchmark for other Authorities in adopting a standard for shift work and working hours.

Within the European Union, there is already a Working Directive enforced from year 2003. The main objective of this *Directive 2003/88/EC*, is to protect workers against excessive working hours and the neglect of rest periods. The *Directive* was issued after evidence showed that long working hours, missed minimum rests, and abnormal working hours was having detrimental effect on health and safety, both for the workers concerned and for the general public.

Work-life balance can also be negatively affected in particular by working irregular hours, or at unusual times. In particular, the interaction of additive factors such as long hours and shift work may have serious effects on health and safety.

The significance of having regulated working hours for personnel involved with safety sensitive task is of great importance and will minimize the risk associated with working long hours or without sufficient rest. As the ever expanding aviation industry within the UAE is a 24 hour nonstop operation, the UAE GCAA should provide detailed guidelines for staff involved in safety sensitive aircraft maintenance tasks to follow regarding maximum days on duty, working hours, shift cycles, working beyond normal





duty times, minimum rest between shifts, rest days and reporting of fatigue or implementation of fatigue risk management system.

## 2.4 Fatigue Risk Management System (FRMS)

Fatigue is widely recognized as a significant safety hazard, not just to an individual and co-workers, but to the general public. Fatigue is a threat to aviation safety because it can have a negative effect on performance.

Perhaps one of the most insidious aspects of fatigue is that when a person is fatigued, they often are unable to recognise that they are fatigued, which affects their performance and that they should respond accordingly with this risk. For aircraft maintenance personnel, who are often shift workers, fatigue is an important issue that should be managed.

The FRMS are widely used to manage fatigue among flight crew, but comprehensive approaches to fatigue risk management for aircraft maintenance personnel are still uncommon among operators and aircraft maintenance organizations. Some countries have detailed guidelines and FRMS for drivers of commercial vehicles.

In the wider transport industry, the objective of most FRMS has been to reduce fatigue to an acceptable level. Two additional objectives can be identified for FRMS in the maintenance environment. Firstly, reducing or capturing fatigue-related errors, and secondly, minimizing the harm caused by fatigue-related errors. A range of countermeasures, as mentioned above, can help to achieve these three objectives in aviation maintenance<sup>54</sup>.

*EASA NPA 2013-1* has mentioned the high importance of addressing fatigue with the statement that, "Maintenance personnel fatigue crystallizes as an area requiring specific attention."

Fatigue is an intrinsic aspect of all scheduled or unscheduled maintenance operations. Numerous studies have shown that all of these conditions heighten aircraft maintenance personnel fatigue in their daily tasks. The NPA stresses the importance of managing safety hazards stemming from maintenance personnel fatigue and proposes the implementation of a safety risk management scheme.

Aircraft mechanics and engineers usually take great pride in their work and often feel committed to getting the aircraft back up and flying and prefer to complete their work, regardless of how long this might take ('can do' attitude). Although there is an organizational control structure within all approved maintenance organisations, maintenance personnel tend to take control of their own working time. Thus, there will always be engineers willing to work excessive hours.

<sup>54</sup> Additional information can also be found at [www.faa.gov/library/reports/medical/oamtechreports](http://www.faa.gov/library/reports/medical/oamtechreports) under DOT/FAA/AM-11/10- *Fatigue Risk Management in Aviation Maintenance: Current Best Practices and Potential Future Countermeasures* written by Hobbs A, Avers KB, Hiles JJ.





**Table 7. Physical and mental manifestations of fatigue**

Physical Manifestations	Mental Manifestations
General feeling of tiredness	Difficulties in memorizing information
Reduction in vigilance	Lack of concentration
Growing and irresistible need to sleep	Periods of inattention
Nodding off/inadvertent napping	Slow understanding
Lethargy	Tendency to forget information and actions
Slowed reaction time	Bad mood , Poor decisions

As each person reacts differently to tiredness, with his mental and physical condition becoming less alert, especially from the start of a shift. Fatigue can manifest itself both physically and psychologically. Table 7 shows some of the major manifestations of fatigue.

ICAO, in its *Human Factors*<sup>55</sup> *manual for maintenance* states that aviation maintenance personnel are subjected to physical and mental fatigue mainly due to excessive hours of work, poor planning, insufficient staffing, poor shift scheduling and a working environment with no proper control of temperature, humidity or noise'. Fatigued maintenance personnel means a higher likelihood of maintenance errors occurring, resulting in potentially harmful occurrences and a decrease in production efficiency, undermining the workforce, aircraft and workplace safety.

During aircraft accident investigations, besides the accident site investigation, many other factors are usually looked at including duty timings of the aircraft maintenance personnel. Even though the Incident did not result in any catastrophic failure or fatalities, from the roster that was in effect, the Operator's maintenance personnel would have accumulated fatigue.

FRMS for aircraft maintenance personnel has already been mandated into the civil regulations of some National Aviation Authorities, but for the UAE GCAA, this has yet to be regulated.

Similar to CAR-OPS regarding flight crew, the implementation of fatigue risk management for personnel involved with safety sensitive work will bring benefits for safety in addition to improving the well-being of maintenance personnel.

<sup>55</sup> <http://srd.mcaa.gov.mn/images/pdf/durem/busad/Doc%209824%20-%20Human%20Factors%20Guidelines%20for%20Aircraft%20Maintenance%20Manual.pdf>



## 2.5 Maintenance Error Data Collection

For the UAE, aviation safety concerns are reported through the GCAA mandatory reporting system called ROSI. The concept of reporting a maintenance error into ROSI is not specifically required as per GCAA CAAP 22, but the UAE GCAA does require operators to report non-compliance, or significant errors in compliance, with required maintenance procedures. As the end user may or may not report this error into ROSI it is unsure to what extent the UAE aviation industry is affected by maintenance errors.

CAAP 22, under Appendix B: List of Examples of Reportable Incidents has addressed fatigue for flight crew as a reportable incident. For aircraft maintenance personnel, there is no mention that fatigue is reportable.

As mentioned in CAAP 22, ROSI is a tool that enables the GCAA to receive reportable occurrences<sup>56</sup> from all GCAA certificate holders and, through analysis, to identify any adverse trends or concerns, then to initiate feedback and / or safety studies intended to enhance aviation safety.

In order to determine maintenance concerns based on ROSI reports, the Investigation initiated a search related to aircraft maintenance human factors, fatigue and maintenance errors. All operators who submitted reports to ROSI from 2010 to 2013 were reviewed. This included 14 ROSI reports from the Operator that were submitted over a 3 year period, 2010 to 2012, and 17 ROSI reports from another MRO that produced approximately 4 million man-hours over four years (2010 to 2013).

As the data was limited regarding the number of reports submitted to the GCAA by the certificate holders, there was no specific trend identifiable, nor any significant findings related to maintenance errors.

Data from UAE GCAA certificate holders should be channeled into a common establishment, preferably the Authority, whereby this information can be de-identified, analyzed and shared with the industry. This approach is being used internationally and research has indicated that by sharing experiences, measures can be put in place to minimize errors and the potential consequences of an error.

Probably, there is a lack of understanding and confidence by GCAA certificate holders to value the benefit of reporting an incident involving maintenance error, especially when there are names of the organization and personnel to be mentioned. The Authority should emphasize the benefits to the industry of data collection and analysis.

The GCAA should publish maintenance safety data analysis reports so that the benefits of reporting can be maximized by providing feedback.

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<sup>56</sup> Refer to GCAA CAAP 22



## 2.6 GCAA Audits

The GCAA audits of the Operator highlighted concerns with SMS implementation, amongst other findings. It was noted that all findings were appropriately actioned by the Operator and accepted by the GCAA.

A review of the Operator's audit reports issued by the GCAA did not contain information as to whether areas of aircraft maintenance staff duty times and related human factors issues such as fatigue, safety culture surveys, safety performance indicators and the effectiveness of human factors training were reviewed as part of the audit scope. As identified in this Investigation, the auditing aspect from the Authority should also encompass other areas that influence staff performance.

Prior to 2008, there was no requirement for the process of management of change except for the requirement in *CAR-145* regarding to manpower planning. As a result, no audit was performed by the GCAA on the Operator's decision to reduce manpower in 2008/2009. After 2011, under *CAR Part X* and detailed in GCAA CAAP 50, management of change has been addressed.

Whenever a company decides to carry out staff reduction especially those that are involved with safety sensitive tasks, there should be a careful and well-structured approach to ensure that safety is not jeopardized. Detailed risk mitigation should be implemented and safety nets, as required, are to be put in place before the decision of staff reduction. The same actions can also be applicable for staff increase as well as when temporary staff is employed. For the Operator's implementation with staff reduction, the Investigation could not determine if this was discussed with the GCAA.



## 3. Conclusions

### 3.1 General

From the evidence available, the following findings, causes and contributing factors were made with respect to this Incident. These shall not be read as apportioning blame or liability to any particular organization or individual.

To serve the objective of this Investigation, the following sections are included under the conclusions heading:

- **Findings-** are statements of all significant conditions, events or circumstances in this Incident. The findings are significant steps in this Incident sequence but they are not always causal or indicate deficiencies.
- **Causes-** are actions, omissions, events, conditions, or a combination thereof, which led to this Incident.
- **Contributing factors-** are actions, omissions, events, conditions, or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the accident or incident occurring, or mitigated the severity of the consequences of the accident or incident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

### 3.2 Findings

#### 3.2.1 Findings related to the Operator

- (a) The Aircraft had a valid certificate of airworthiness (C of A) and was certified, equipped, and maintained in accordance with existing UAE *Civil Aviation Regulations*.
- (b) From the records provided, both pilots were current with their certificates and had the required rest prior to the Incident flight.
- (c) The pre-departure passenger safety briefing, provided in the English language only, was delivered while the aircraft was taxiing, and the cabin was noisy.
- (d) The Passenger mentioned that the safety briefing was inaudible.
- (e) The CCM evaluated the situation and entered the cockpit during a critical phase of flight.
- (f) The CCM left his seat with the seat belt sign on to attend to the concerns of the passenger.
- (g) The Engineer held the appropriate UAE GCAA aircraft maintenance license and Operator's approval for the Aircraft type.
- (h) Review of the Engineer's records that was kept with the Operator's quality department was unblemished.
- (i) The Engineer, prior to the Incident, had worked an average of 8.5 hours per day for 32 days with 2 staggered days off.



- (j) The day before the Incident, the Engineer had worked until 0130 LT, which was 3.5 hours after the end of the normal duty time.
- (k) The LH engine was installed on the Aircraft on 11 July 2012. The RH engine was installed on 7 September 2012, two days before the Incident.
- (l) The additional engine compressor desalination washes started after 11 July 2012 on this Aircraft only.
- (m) During 8 September 2012 afternoon shift, both the LH and RH engines were prepared for engine turbine washes by the Engineer. One igniter, on the LH side of each engine was removed.
- (n) Two mechanics prepared the Aircraft for engine compressor desalination washes by removing the access plug, one for each engine. The mechanics performed the engine compressor desalination washes only, on both engines.
- (o) The mechanics did not refer to the *AMM*, or any other technical instruction, for the engine compressor washes.
- (p) Turbine water washes were not performed on the Aircraft
- (q) The mechanics did not sign any document for the work they performed on the Aircraft.
- (r) The Engineer accepted the mechanic's verbal confirmation and assumed that the turbine washes had been carried out and that the igniter plugs were normalized. He did not ensure, by physical inspection, that this was the case.
- (s) The Engineer certified the engine turbine washes of both engines without verifying the work was performed.
- (t) The Engineer declared the Aircraft airworthy for flight.
- (u) The igniters removed in preparation for the turbine washes were not reinstalled for the flight.
- (v) The flight crew were not aware that the first engine runs of the day were verification engine runs related to maintenance action carried out on the Aircraft.
- (w) The gradual discoloration of the nacelle panel commenced shortly after engine start.
- (x) The temperature of the uncontrolled hot gases escaping from the igniter boss was approximately 500°C.
- (y) The nacelle design for venting hot gases from the engine compartment aided in dissipating the escaping gases.
- (z) The LH igniters from both engines were found lying inside the engine compartments.
- (aa) The electrical harness that connects to the LH igniters was not connected.
- (bb) Evidence of black soot, indicating signs of overheating, was found within the engine compartments of both engines, including on the structure and tubings.
- (cc) No signs of overheating were observed on the compartment fire detectors, which were located approximately 16.5 inches from the open port.



- (dd) Both engine RH igniter plugs and harnesses were intact and installed.
- (ee) No abnormal cockpit indications were generated during the flight.
- (ff) The flight crew were not aware that the engine igniters were not installed.
- (gg) The Operator's engineering document *Task A7200/01* for engine turbine wash was removed in December 2011
- (hh) *EGEN F/W 11*, issued in December 2011 replaced task A7200/01 for the engine turbine washes.
- (ii) *EGEN F/W 11* did not have any provision for sign-off.
- (jj) *EGEN F/W 11* sign-off was a stamp entered in the Aircraft technical log, which was certified by the Engineer
- (kk) Upon normalizing the engine, including the installation of the igniter plug, an engine ground run is performed, but only if the engine is not started within the next 12 hours.
- (ll) The *P&WC maintenance manual* states that the engine run after this wash is optional.
- (mm) The additional engine compressor wash introduced by the supervisors was intended only to be accomplished on the LH engine fitted on the Incident Aircraft, as that engine was installed in July 2012.
- (nn) This additional compressor wash was neither included in the *Aircraft maintenance program*, nor was it controlled by the maintenance planning department.
- (oo) No task card for the compressor wash had been issued by the maintenance supervisors.
- (pp) The work performed was not documented and was not signed off by a certifying engineer.
- (qq) No entries had been made in the Operator's electronic data entry system (RUSADA) indicating that the engine washes were performed.
- (rr) Two mechanics normalized the engines' compressor plugs, sense lines and then closed the engines' panels.
- (ss) There was no fire or overheat warning as a result of the uncontrolled escaping hot gases during the flight. After the Incident, testing of the engines ignition systems and fire detectors did not reveal any anomalies.
- (tt) The Operator went through a staff reduction in years 2008/2009. No management of change was carried out prior to this staff reduction.
- (uu) The Operator did not consider engine washes to be a critical task and that items removed for this task should require re-inspection by a second engineer based on *MOE, section 2.23- Control of Critical Tasks*.
- (vv) Although the engine compressor wash task had started two months prior to the Incident, the obligations of the Operator, as a *CAR-M* and *CAR-145* certificated organization, were not practiced in that no audits were carried out on





documentation, maintenance sign-offs, entering data into RUSADA, and shift handover.

- (ww) The Engineer's roster, and the rosters of other maintenance personnel requires them to work on an 8.5-hour shift per day, inclusive of a one-hour break, for 56 consecutive days, rotating between an early start day shift [E] from 0600 to 1430 LT, and a late shift [L] from 1330 to 2200 LT.
- (xx) After 56-days on-duty, the employees are rostered off for 28 consecutive days leave.
- (yy) A risk assessment and identification of potential hazards for maintenance staff duty times was not made available to the Investigation.
- (zz) The Operator has no procedure for measuring and mitigating the effects of fatigue for aircraft maintenance personnel, and this is not required by the regulator.
- (aaa) There was no evidence of maintenance personnel reporting fatigue issues through the internal safety reporting system.
- (bbb) The Operator released the Aircraft in contravention of *CAR 145.50* Certification of Maintenance, since un-recorded work had been performed, and the left engine igniters on both engines had not been re-installed.
- (ccc) Maintenance personnel had received human factors training.
- (ddd) Even though the Operator had a maintenance error management system (MEMS) in place, no data or reports were provided to the Investigation.
- (eee) As per the Operator's *MOE*, MEMS is a procedure under the responsibility of the Quality Department. This is inconsistent with auditing and investigative principles, which require independence of, and separation of, the audit and investigation processes.

### 3.2.2 Findings related to the GCAA

- (a) A review of the UAE regulations pertaining to *Part-145* and *CAR-145* approved organizations; the GCAA does not specify that certificate holders performing aircraft maintenance must employ an FRMS system. In addition, there are no specific instructions or guidelines that can be referred to by a GCAA certificate holder that wishes to implement an FRMS system.
- (b) Similar to *CAR-OPS*, the GCAA does not have any regulations detailing working hours and duty times for personnel involved in aircraft maintenance.
- (c) As mentioned in point (b) above, GCAA Inspectors were not required to review the duty timings of the Operator's aircraft maintenance personnel.
- (d) From the ROSI data provided to the Investigation, due to the small number of reports, the data was not sufficient for any scientific analysis.
- (e) Currently, sharing of information, as mentioned in section 1.18.7 of this Report, is limited within the GCAA.
- (f) It was noted by the Investigation that analytical trend reports, or reports of safety concerns related to maintenance errors collected from ROSI reports, or



feedback to the aviation industry, is not available from the GCAA for the benefit of aviation safety.

- (g) CAAP 22, *Appendix B- List of Examples of Reportable Incidents*, addressed fatigue for flight crew as a reportable incident. For aircraft maintenance personnel, there is no requirement to report fatigue.
- (h) The GCAA audit findings on the Operator highlighted SMS deficiencies including inadequate staffing.
- (i) A GCAA audit finding indicated that there was no record indicating that the Operator's quality assurance had audited any aspect of the SMS as per *CAR Part X*.
- (j) The GCAA audit finding mentions that the Operator had insufficient aircraft maintenance manpower for the planned workload.

### 3.3 Causes

The Air Accident Investigation Sector determines that the cause, of this incident, which resulted in an 'in-flight turn back', was due to the omission to reinstall the left engine igniters on both of the aircraft's engines following maintenance work. The maintenance error occurred as result of a number of contributing factors.

#### 3.3.1 Contributing Factors

The Contributing factors to the event were:

- (a) Unrecorded maintenance work performed on the Aircraft by the Operator's maintenance personnel.
- (b) Introduction of an engine wash without a maintenance task card.
- (c) Engineer signed off work on the Aircraft without verifying that the work had been performed.
- (d) Mechanics performed unsupervised work.
- (e) Mechanics performed engine motoring without the Operator's approval.
- (f) Work was performed on the Aircraft without maintenance task card.
- (g) Engine washes were not considered a critical task by the Operator.
- (h) Performing similar tasks on both engines during the same maintenance visit.
- (i) Not carrying out an engine run after the engine washes were performed
- (j) Not performing a system check of the engine ignition system after engine wash normalization.
- (k) Not attaching a telltale streamer to indicate that parts have been removed and are in a concealed area.
- (l) Operator's quality oversight, as unrecorded work was being performed regularly prior to the Incident.
- (m) Mechanics not signing for work performed, following engine washes.



- (n) The removal, in 2009, of the engine wash card which was requiring a signature by the mechanic, before the engineer signoff.
- (o) The effect of fatigue on the decision making process of the Engineer due to his shift pattern of working an average of 8.5 hours a day for 32 days with 2 staggered days off.
- (p) The Engineer, in addition to supervising the shift work, was required to enter data into the Operator's electronic system.
- (q) Application of the Operator's human factors training, as unrecorded work was a practice associated with engine washes.
- (r) The Operator's SMS implementation, since there were GCAA audit findings between 2009 and 2012.
- (s) Lack of guidance provided by the GCAA, and the Operator, of the effect of shift duty times, and management of the risk associated with fatigue.



## 4. Safety Recommendations

### 4.1 General

Safety actions taken after the Incident are described in paragraph 4.2.

The safety recommendations are proposed according to paragraph 6.8 of *Annex 13 to the Convention on International Civil Aviation*<sup>57</sup>, and are based on the conclusions listed in heading 3 of this Report. The GCAA expects that all safety issues identified by the Investigation will be addressed by the receiving States and organizations.

### 4.2 Safety Actions Taken by the Operator

#### 4.2.1 Internal Recommendations

1. The internal Company Crew Resource Management (CRM) and Human Factors (HF) programs use this occurrence to demonstrate how barriers can degrade the safety of flight.

2. New and/or suggested improvements are reviewed, formally risk assessed, and adequately communicated, as part of a Management of Change (MOC) process, prior to their implementation.

3. As of 2014, the Operator has demonstrated an effective and compliant implementation of Safety Management System (SMS) requirements as per *CAR Part X*.

#### 4.2.2 Action Taken – TIB 72-005, 72-006 and 72-010

Shortly after the event, and as recommended by the ongoing investigation, a *Technical Information Bulletin (TIB)* was published to outline new controls and procedures to eliminate any potential recurrence of this type of event. The main controls include the requirements to flag removed igniters (until they are re-installed), and to raise and carry out a Duplicate Inspection as per *EGEN # 39*. The complete TIBs are attached in section 5, Appendices.

#### 4.2.3 Action Taken – ROSI Reporting

The Operator's quality department was in charge of the ROSI submissions to the GCAA until January 2013. At the request of the newly appointed safety postholder, the internal ROSI submission responsibility was transferred to the safety department in February 2013.

### 4.3 Final Report Safety Recommendations

The Air Accident Investigation Sector recommends that:

<sup>57</sup> Paragraph 6.8 of *Annex 13 to the Convention on International Civil Aviation* states: 'At any stage of the investigation of an accident or incident, the accident or incident investigation authority of the State conducting the investigation shall recommend in a dated transmittal correspondence to the appropriate authorities, including those in other States, any preventive action that it considers necessary to be taken promptly to enhance aviation safety'.



#### 4.3.1 Abu Dhabi Aviation should

##### SR45/2015

review the process of identifying aircraft maintenance critical tasks and not limit this review process to engine washes.

##### SR46/2015

review the practical implementation of aircraft maintenance human factors training and SMS awareness training. The documenting and signing for work performed on an aircraft should be emphasized during this training.

##### SR47/2015

review and implement procedures, in line with SMS best practice, for risk mitigation for activities affecting aircraft maintenance.

##### SR48/2015

review its procedures and implement control measures with regards to aircraft maintenance:

1. When unsupervised work has to be performed.
2. To implement best practices for conducting maintenance but not limited to, the use of work cards for maintenance tasks, especially those involving safety-critical functions that promote the recording and verification of delineated steps in the task that, if improperly completed, could lead to a loss of control.
3. Provide data entry support for aircraft maintenance personnel.

##### SR49/2015

implement measures to enhance quality audit oversight in line with the requirements of the GCAA.

##### SR50/2015

implement measures to have a safe cabin environment regarding passenger safety briefings so that announcements are audible and intelligible during all flight phases.

##### SR51/2015

review CRM training between the flight crew and cabin crew that can add benefit to the flight crew decision making process.

##### SR52/2015

ensure organizational and functional independence, between the audit and investigation processes, of the maintenance error management system, MEMS.



#### 4.3.2 The General Civil Aviation Authority of the United Arab Emirates should

##### **SR53/2015**

issue guidance to the industry for workers involved with safety sensitive jobs regarding to man-hour methodology, duty timings, including maximum days on duty, working hours, shift pattern, working beyond normal duty times, minimum rest between shifts and rest days.

##### **SR54/2015**

issue guidance to the industry for workers involved with safety sensitive jobs regarding fatigue risk management.

##### **SR55/2015**

establish a common data depository for collecting information on maintenance safety issues and errors, from UAE GCAA certificate holders, whereby the information can be de-identified, analyzed and the results made available to the industry.

##### **SR56/2015**

gather maintenance errors and hazard identification information and should:

1. Disseminate this information to all UAE operators and certificate holders so that they are aware of the areas of concern that have been identified
2. That this information to be inserted within the certificate holders training.
3. Access of this information should be available on the GCAA website for the benefit of the aviation industry.

##### **SR57/2015**

amend CAAP 22 to include that aircraft maintenance personnel should report fatigue in a similar manner as aircrew report fatigue.

##### **SR58/2015**

audit Operators with regarding *CAR-OPS 1.695* with specific reference to the audibility and intelligibility of the passenger address system.

This Report is issued by:

**The Air Accident Investigation Sector  
General Civil Aviation Authority  
United Arab Emirates.**





## 5. Appendices

### Appendix A- CAR 145.47 on Production Planning

CAR 145.47- Production planning, states:

- "(a) The organisation shall have a system appropriate to the amount and complexity of work to plan the availability of all necessary personnel, tools, equipment, material, maintenance data and facilities in order to ensure the safe completion of the maintenance work.
- (b) The planning of maintenance tasks, and the organising of shifts, shall take into account human performance limitations.
- (c) When it is required to hand over the continuation or completion of maintenance tasks for reasons of a shift or personnel changeover, relevant information shall be adequately communicated between outgoing and incoming personnel."

AMC 145.47(a)- Production planning, states:

- "1. Depending on the amount and complexity of work generally performed by the maintenance organisation, the planning system may range from a very simple procedure to a complex organisational set-up including a dedicated planning function in support of the production function.
2. For the purpose of CAR-145, the production planning function includes two complementary elements:
- Scheduling the maintenance work ahead, to ensure that it will not adversely interfere with other work as regards the availability of all necessary personnel, tools, equipment, material, maintenance data and facilities.
  - During maintenance work, organising maintenance teams and shifts and provide all necessary support to ensure the completion of maintenance without undue time pressure.
3. When establishing the production planning procedure, consideration should be given to the following:
- Logistics, Inventory control, Square meters of accommodation, Man-hours estimation, Man-hours availability, Preparation of work, Hangar availability, Environmental conditions (access, lighting standards and cleanliness), Co-ordination with internal and external suppliers, etc., and Scheduling of safety-critical tasks during periods when staff are likely to be most alert."

AMC145.47(b)- Production planning, states:

"Limitations of human performance, in the context of planning safety related tasks, refers to the upper and lower limits, and variations, of certain aspects of human performance (Circadian



rhythm/24 hours body cycle) which personnel should be aware of when planning work and shifts."

AMC145.47(c) Production planning, states:

"The primary objective of the changeover/handover information is to ensure effective communication at the point of handing over the continuation or completion of maintenance actions. Effective task and shift handover depends on three basic elements:

- The outgoing person's ability to understand and communicate the important elements of the job or task being passed over to the incoming person.
- The incoming person's ability to understand and assimilate the information being provided by the outgoing person.
- A formalized process for exchanging information between outgoing and incoming persons and a planned shift overlap and a place for such exchanges to take place."

## **Appendix B- Working time guidelines from UK CAA CAP 716**

In summary, the working time guidelines, which are contained in CAP 716, introduced:

- Limit of an average of 48 hours a week which a worker can be required to work (though workers can choose to work more if they want to).
- Limit of an average of 8 hours' work in 24 hours which night workers can be required to work.
- Right for night workers to receive free health assessments.
- Right to 11 hours rest a day.
- Right to a day off each week.
- Right to an in-work rest break if the working day is longer than six hours.
- Right to four weeks paid leave per year.
- Workers cannot be forced to work for more than 48 hours a week on average.
- Young Workers (under 18) may not ordinarily work more than 8 hours a day or 40 hours a week, although there are certain permitted exceptions.
- Working time includes travelling where it is part of the job, working lunches and job-related training.
- Working time does not include travelling between home and work, lunch breaks, evening classes or day-release courses.
- The average weekly working time is normally calculated over 17 weeks. This can be longer in certain situations (26 weeks) and it can be extended by agreement (up to 52 weeks - see DTI website for more details)
- Workers can agree to work longer than the 48-hour limit. An agreement must be in writing and signed by the worker. This



is generally referred to as an opt-out. It can be for a specified period or a indefinite period. There is no opt-out available from the Young Workers limits.

- Workers can cancel the opt-out agreement whenever they want, although they must give their employer at least seven days' notice, or longer (up to three months) if this has been agreed.

- The working time limits do not apply if workers can decide how long they work (i.e. elect to sign an opt-out)."

CAP 716, based on the UK working time legislation, also gives guidelines on Working at Night:

- A night worker is someone who normally works at least three hours at night.

- Night time is between 11pm and 6am, although workers and employers may agree to vary this.

- Night workers should not work more than eight hours daily on average, including overtime where it is part of a night worker's normal hours of work.

- Nightly working time is calculated over 17 weeks. This can be longer in some situations.

- A night worker cannot opt-out of the night work limit

- Young workers should not ordinarily work at night, although there are certain exceptions (please see DTI website for more details)."

As this legislation did not guarantee that individuals will be prevented from working excessive hours, in some cases (e.g. 'opt-outs' for instance), and it did not guarantee avoidance of fatigue, the UK CAA funded a study to produce best practice guidelines for work hours within the aviation maintenance industry which, if applied appropriately by organisations and individuals, should help reduce potential problems with fatigue among staff. This study was conducted by Professor Simon Folkard and is detailed in CAP 716.

## Appendix C- EASA NPA 2013-1 on Fatigue

EASA in its proposed changes, stated in NPA 2013-1 section AMC1- 145.A.46 (b)- *Production Planning Fatigue Risk Management*:

"(a) In order to manage the fatigue related risk of personnel, as an aviation hazard, the organisation should:

(1) As part of its safety policy develop and maintain a policy for the management of fatigue related risk and define the related procedures.

(2) Define and use a work schedule scheme with maximum work and minimum rest hours not exceeding the limitations laid down in the Directive 2003/88/EC.

Where temporary derogations and opt-outs to Directive 2003/88/EC are agreed between the organisation and its personnel, the organisation should conduct and document



a risk assessment, and take the necessary actions to mitigate the applicable risks.

(3) Ensure existing reporting systems enable the identification of fatigue related hazards.

(4) Assess and manage the risks of such fatigue related hazard reports in accordance with the organisation's safety risk management procedures in accordance with AMC1 145.A.65(a)(3), and monitor the effectiveness of related risk mitigation actions implemented.

(5) Provide training on the management of fatigue.

(b) By derogation from point (a)(2) above, when the organisation does not apply the maximum work and minimum rest hours laid down in the Directive 2003/88/EC11, it should establish as part of its management system a fatigue risk management scheme in accordance with AMC2 145.A.65(a)(3) acceptable to the competent authority."

AMC2 145.A.65(a)(3) contains the following under Fatigue Risk Management Scheme:

(a) When a Fatigue Risk Management (FRM) scheme is implemented, the organisation should establish, implement, document, and maintain the FRM scheme as an integral part of its management system.

(b) The FRM scheme should:

- (1) Incorporate scientific principles and knowledge
- (2) Manage the operational risk(s) of the organisation arising from fatigue of personnel on an on-going basis
- (3) Ensure that actions necessary to effectively mitigate the organisation's risk(s) arising from fatigue, are implemented promptly;
- (4) Provide for continuous monitoring and regular assessment of the mitigation of fatigue risks achieved by such actions;
- (5) Provide for continuous improvement to the overall performance of the FRM scheme; and
- (6) Be supported by the organisation's just culture policy to ensure confidence in reporting fatigue related hazards.

(c) The FRM scheme should make use of the organisation's general management system processes in terms of hazard identification and safety risk management. It should reflect the size, nature, and complexity of the organisation and its operational working hours.

(d) All personnel involved in maintenance activities under a FRM scheme should receive FRM training to ensure competence commensurate with the roles and responsibilities of management, certifying engineers, and support staff.



(e) Records of all FRM output, including findings from collected data, recommendations, and actions taken, should be maintained in accordance with the organisation's general record keeping procedures."

## Appendix D- Australia CASA MOS AMC 145.A.65 on Fatigue

The Australia Civil Aviation Safety Authority, CASA, under *Civil Aviation Safety Regulations (CASR)*, MOS AMC 145.A.65 (b) 1,6- *Fatigue and Impairment Management* states that the management system should include:

- "(a) A Drug and Alcohol Management Plan (DAMP) as required by CASR Part 99
- (b) The uses of a defined set of guidelines on maximum duty hours to be worked within set periods (daily/weekly/monthly) and rostering practices to be employed to ensure that employees do not become, or accumulate an excessive level of fatigue from their rostered and overtime duty periods; or
- (c) A Fatigue Risk Management System (FRMS)."

In addition, CASA has recommended guidelines for maintenance organizations in developing an FRMS and is based on the research done by Professor Simon Folkard for the UK CAA (CAP 716). The details can be found under *CASR MOS GM145.A.65 (b) 1, d- Fatigue and Impairment Management*.

The following is a summary of CASR MOS GM145.A.65 (b) 1,d:

- a. "Minimise the build-up of fatigue over periods of work.
- b. Maximise the dissipation of fatigue over periods of rest.
- c. Minimise sleep problems and circadian disruption.
- d. No scheduled shift should exceed 12 hours.
- e. No shift should be extended beyond a total of 13 hours by overtime.
- f. A minimum rest period of 11 hours should be allowed between the end of shift and the beginning of the next, and this should not be compromised by overtime.
- g. A maximum of four hours' work before a break.
- h. A minimum break period of ten minutes plus five minutes for each hour worked since the start of the work period or the last break.
- i. Scheduled work hours should not exceed 48 hours in any period of seven successive days.
- j. Total work; including overtime, should not exceed 60 hours or seven successive work days before a period of rest days.
- k. A period of rest days should include a minimum of two successive rest days continuous with the 11 hours off between



shifts (i.e. a minimum of 59 hours off). This limit should not be compromised by overtime."

## Appendix E- Operator's A7200/01 Engine Turbine Wash

Task Card Number A7200/01- Dated May 2009 Rev 1.

<p style="text-align: center;"><b>ENGINE TURBINE WASH</b></p> <p><b>TASK DESCRIPTION:</b> Engine Cleaning, Turbine Wash, Method 2  <b>INTERVAL:</b> Daily  <b>REFERENCE:</b> P&amp;WC PW123 MM Chapter 72-00-00  <b>TASK:</b> Clean  <b>ZONE(S):</b> 418, 428  <b>ACCESS:</b> 415AL, 425AL</p> <p><b>EQUIPMENT AND MATERIALS:</b>          (1) Turbine Wash Nozzle, P/N PWC 56502          (2) Demineralized Water</p> <p><b>PROCEDURE:</b></p> <p><b>NOTE:</b> Task is applicable to #1 and #2 engines.</p> <ol style="list-style-type: none"> <li>(1) Open access panels 415AL, 425AL.</li> <li>(2) Remove left side igniter and install the turbine wash nozzle.</li> <li>(3) Connect wash rig hose to the wash nozzle.</li> <li>(4) Carry out the remainder of engine turbine washes in accordance with P&amp;WC MM 72-00-00, Engine Cleaning, Step C – Turbine Wash, <b>Method 2</b>.</li> <li>(5) Disconnect the wash rig hose.</li> <li>(6) Install the igniter and gasket.</li> <li>(7) Close access panels 415AL and 425AL.</li> <li>(8) Carry out an engine-drying run unless the engine is to be started within the next 12 hours.</li> </ol>	<p><b>Aircraft Reg:</b> <input type="text"/></p> <p><b>Worksheet No:</b> <input type="text"/></p> <p><b>Hours:</b> <input type="text"/></p> <p><b>Cycles:</b> <input type="text"/></p> <p><b>Date:</b> <input type="text"/></p>
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FITTER			
Name:	Signature:	Date:	Man Hours:

LICENCED AIRCRAFT ENGINEER				
Certifies that the work specified except as otherwise indicated was carried out in accordance with CAR 145 and in respect to that work the aircraft/aircraft component is considered fit for release to service.				
UAE GCAA Approval EM/ADA/89				
Name:	Signature:	Auth Number	Date:	Man Hours:

Form: 175

**A7200/01** Page 1 of 1  
Rev 1 May 09





## Appendix F- Operator's EGEN F/W 11 Issued Dec- 2011

The following was an internal procedure issued by the Operator that replaced Task A7200/01:

*EGEN F/W 11 is an internal procedure defining engine wash procedures as follows:*

- 1. Enter in aircraft defect section column of the aircraft technical log book "Engine turbine wash required";*
- 2. Ensure that an adequate amount of de-mineralized water is available in F/W truck and that the pressure is adequate;*
- 3. Open the access panels 415AL and 425AL;*
- 4. Remove the left hand side igniter plug and install the turbine wash nozzle;*
- 5. Connect the wash rig hose to the wash nozzle installed in the igniter plug position;*
- 6. Carry out the remainder of the engine turbine wash in accordance with Pratt & Whitney Maintenance Manual Chapter 72-00-00 Engine Cleaning, Step C – Turbine Water Wash, Method 2;*
- 7. On completion of the wash disconnect the wash rig hose from the igniter plug position and remove the turbine wash nozzle;*
- 8. Install the igniter plug and gasket;*
- 9. Close the access panels 415AL and 425AL;*
- 10. Carry out an engine-drying run unless the engine is to be started within the next 12 hours; and*
- 11. Enter in the technical log action taken section "Engine Turbine water wash C/O IAW P&WC MM 72-00-00 Engine cleaning step C Turbine water wash, Method 2"*



## Appendix H- Operator's TIB 72-005 Dated Nov-2012<sup>58</sup>

### Technical Information Bulletin

A/C	Dash 8	ATA	72	Seq. No	72-005	Rev. No	1
Description		Engine Cleaning, Performance Recovery Wash					
References		Pratt & Whitney M.M 72-00-00 pages 716 to 719					
Applicability		Dash 8 – 200/300					
Issued By				Date	November 2012		
Approved By		Engineering Director		Validity	Indefinite		

#### Introduction

To improve the reliability of aircraft powerplants, the performance recovery wash is performed at each EMP. Inspection.

#### Procedure:

TASK DESCRIPTION: Engine Cleaning, Performance Recovery Wash,  
INTERVAL: EMP  
REFERENCE: P&WC PW123 MM Chapter 72-00-00  
TASK: Performance Wash Procedure  
ZONE(S): 418, 428  
RH Nacelle : 423AL, 424AR, 422AT, 427AB  
ACCESS: LH Nacelle : 412AT, 413AL, 414AR, 417AB.

**NOTE 1 :** Ensure that an adequate amount of de-mineralized water is available in F/W truck and that the pressure is adequate in the water tank.

**NOTE 2 :** A hand wash of the engine air intake gas path up to including the flanged joint recommended to be carried out prior to starting the wash procedure. Use sponge dipped in mixture of drinking quality water and detergent gel or equivalent mild detergent. After the wash rinse with clean water to removed the soap residue.

**NOTE 3 :** Task is applicable to powerplant #'s 1 & 2.

**NOTE 4 :** All disconnected components to be flagged.

#### Instruction

1. Enter in aircraft technical log book "defect section column"
  - (a) 'Powerplant # 1 Cleaning, Performance Recovery Wash to be carried out. Flow Divider/Dump Valve Fuel Drain Line and P3 Air Pressure Line disconnected'.
  - (b) 'Powerplant # 2 Cleaning, Performance Recovery Wash to be carried out. Flow Divider/Dump Valve Fuel Drain Line and P3 Air Pressure Line disconnected'.
2. Raise separate work sheet in RUSADA for each powerplant.
3. Open access panels.
  - a. RH Nacelle: 423AL, 424AR, 427AB, 422AT.
  - b. LH Nacelle: 412AT, 413AL, 414AR, 417AB.
4. Disconnect flow divider/dump valve fuel drain line and install cap on drain connection.
5. Disconnect P3 air Pressure sensing tube at intercompressor case end and discard gasket. Install blank over end of tube. Discard Gaskets and "O" Rings removed.
6. Carry out the remainder of performance recovery washes in accordance with
  - a) P&WC MM 72-00-00, Engine Cleaning, Subpart {11} (pages 716-719)
7. All the consumable eg: Gasket's, "O"Ring's to be replaced upon of completion of task.
8. Removed cap on drain connection along with the plastic bag at P3 line.
9. Reconnect flow divider/dump valve fuel drain line and P3 Line.

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Nov 2012

<sup>58</sup> Page 4 of 4 not attached to this Report as it was Internationally left blank by the Operator

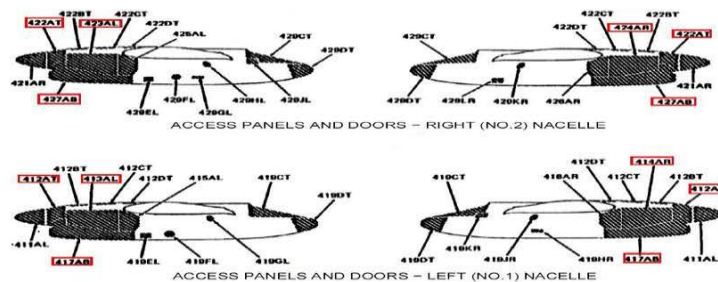


### Technical Information Bulletin

10. Close access panels
  - a. RH Nacelle: 423AL, 424AR, 427AB, 422AT.
  - b. LH Nacelle: 412AT, 413AL, 414AR, 417AB.
11. Carry out engine-drying run and leak checks.
12. Enter in technical log "action take section".
  - (a) "Powerplant # 1 Cleaning, Performance Recovery Wash c/o I.A.W P&WC MM 72-00-00, subpart (11) Flow Divider/Dump Valve Fuel Drain Line and P3 Air Pressure Line Re-connected" worksheet # XXXXXXXX refers.
  - (b) "Powerplant # 1 Cleaning, Performance Recovery Wash c/o I.A.W P&WC MM 72-00-00, subpart (11) Flow Divider/Dump Valve Fuel Drain Line and P3 Air Pressure Line Re-connected" worksheet # XXXXXXXX refers.
13. Each Powerplant Cleaning Performance recovery wash to be accomplished by two different engineers.
14. Each Powerplant to be certified release to service by independent engineer.
15. Duplicate inspection to be raised and carried out as per GEN 39.
  - a. "Powerplant # 1 Flow Divider/Dump Valve Fuel Drain Line and P3 Air pressure Line connection & security".
  - b. "Powerplant # 2 Flow Divider/Dump Valve Fuel Drain Line and P3 Air pressure Line connection & security".

**NOTE:** All Abu Dhabi Aviation PW123 engines are post:

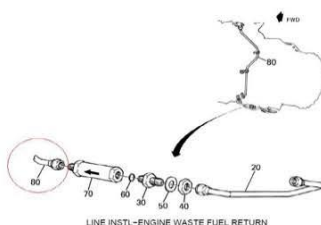
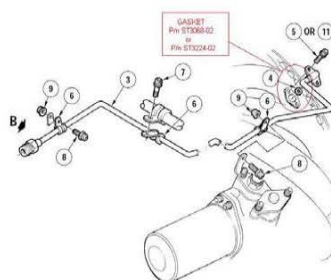
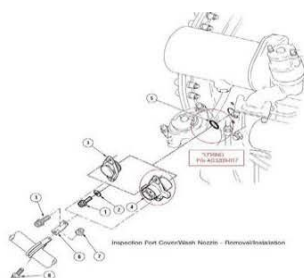
- ✓ SB20948
- ✓ SB21053
- ✓ SB21136





## Technical Information Bulletin

### Engine Cleaning, Performance Recovery Wash



Engineering Director

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## Appendix I- Operator's TIB 72-006 Dated Nov-2012<sup>59</sup>

### Technical Information Bulletin

A/C	Dash 8	ATA	72	Seq. No	72-006	Rev. No	1
Description		Engine Cleaning, Turbine Wash, Method 1					
References		Pratt & Whitney M.M 72-00-00 pages 719 to 723					
Applicability		Dash 8 – 200/300					
Issued By				Date		November 2012	
Approved By		Engineering Director		Validity		Indefinite	

#### Introduction

To improve the reliability of the aircraft powerplants, the turbine wash is performed before the first flight of the day.

#### Procedure:

**TASK DESCRIPTION:** Engine Cleaning, Turbine Wash, Method 1  
**INTERVAL:** Daily  
**REFERENCE:** P&WC PW123 MM Chapter 72-00-00  
**TASK:** Clean  
**ZONE(S):** 418, 428  
**ACCESS:** 415AL, 425AL

**NOTE 1:** Ensure that an adequate amount of de-mineralized water is available in F/W truck and that the pressure is adequate in the water tank.

**NOTE 2 :** Task applicable to powerplant #'s 1 & 2.

**NOTE 3 :** All the removed components' to be flagged.

#### Instruction

1. Enter in aircraft technical log book "defect section column"
  - (a) 'Powerplant # 1 Cleaning, Turbine Wash to be carried out'.
  - (b) 'Powerplant # 2 Cleaning, Turbine Wash to be carried out'.
2. Raise separate work sheet in RUSADA for each powerplant.
3. Open access panels.
  - a. **Powerplant # 1 LH** access nacelle door : 425AL.
  - b. **Powerplant # 2 LH** access Nacelledoor : 415AL.
4. Remove left side igniter and install the turbine wash nozzle .  
(P/No PWC37771 highlighted on figure 705 item 3)
5. Disconnect flow divider/dump valve fuel drain line and install cap on drain connection.
6. Connect wash rig hose to the wash nozzle.
7. Carry out the remainder of turbine washes in accordance with
  - a) Pratt & Whitney M.M 72-00-00 Step C (3) Method 1 pages 719 to 723.
8. Disconnect the wash rig hose.
9. Install the igniter (Torque 300 to 360 Lb.in) along with new gasket.  
(gasket P/No 3010880 highlighted on figure 705 item 2 )
10. Reconnect flow divider, dump valve, fuel drain line.

<sup>59</sup> Page 4 of 4 not attached to this Report as it was Internationally left blank by the Operator



### Technical Information Bulletin

11. Close access panels.
  - c. **Powerplant # 1** LH access nacelle door : 425AL.
  - d. **Powerplant # 2** LH access Nacelledoor : 415AL.
12. Carry out engine-drying run and leak checks.
13. Enter in technical log **"action take section"**.
  1. "Powerplant # 1 Cleaning, Powerplant Turbine Wash c/o I.A.W P&WC MM 72-00-00, Step C (3) Method 1 Flow Divider/Dump Valve Fuel Drain Line Re-connected "worksheet # xxxxxxxx refers.
  2. "Powerplant # 2 Cleaning, Powerplant Turbine Wash c/o I.A.W P&WC MM 72-00-00, Step C (3) Method 1 Flow Divider/Dump Valve Fuel Drain Line Re-connected "worksheet # xxxxxxxx refers.
14. Each powerplant cleaning , Turbine wash method 1 to be accomplished by two different engineers
15. Each powerplant to be certified by independent engineer
16. Duplicate Inspection to be raised and carried out as per GEN 39
  - a. "Powerplant # 1 Igniter installation, Flow Divider/Dump Valve Fuel Drain Line and P3 Air pressure Line connection & security".
  - b. "Powerplant # 2 Igniter installation, Flow Divider/Dump Valve Fuel Drain Line and P3 Air pressure Line connection & security".

**NOTE :** All Abu Dhabi Aviation PW123 engines are post:

- ✓ SB20948
- ✓ SB21053
- ✓ SB21136



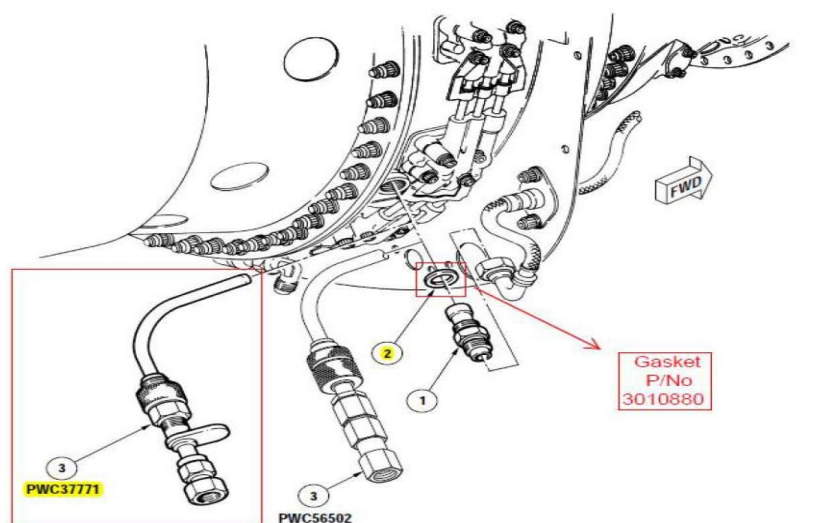
Figure 1





### Technical Information Bulletin

#### Engine Cleaning, Turbine Wash, Method 1



### **INFORMATION ONLY**

C12552A

Turbine Wash Nozzle Connection (Pre-SB20836) - Removal/Installation  
Figure 705

®&WC Proprietary Information. Subject to the restrictions on the title page.

**72-00-00** Page 722  
ENGINE - CLEANING/PAINTING Aug 06/2010

Engineering Director

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## Appendix J- Operator's TIB 72-010 Dated Nov-2012<sup>60</sup>

### Technical Information Bulletin

A/C	Dash 8	ATA	72	Seq. No	72-010	Rev. No	1
Description		Engine Cleaning, Desalination Wash					
References		Pratt & Whitney M.M 72-00-00 pages 711 to 715					
Applicability		Dash 8 – 200/300					
Issued By				Date	November 2012		
Approved By		Engineering Director		Validity	Indefinite		

#### Introduction

To improve the reliability of aircraft powerplants, the performance recovery wash is performed at each EMP. Inspection.

#### Procedure:

TASK DESCRIPTION: Engine Cleaning, Desalination Wash,  
INTERVAL: EMP  
REFERENCE: P&WC PW123 MM Chapter 72-00-00  
TASK: Performance Wash Procedure  
ZONE(S): 418, 428  
RH Nacelle : 423AL, 424AR, 422AT, 427AB  
ACCESS: LH Nacelle : 412AT, 413AL, 414AR, 417AB.

**NOTE 1 :** Ensure that an adequate amount of de-mineralized water is available in F/W truck and that the pressure is adequate in the water tank.

**NOTE 2 :** A hand wash of the engine air intake gas path up to including the flanged joint recommended to be carried out prior to starting the wash procedure . Use sponge dipped in mixture of drinking quality water and detergent gel or equivalent mild detergent. After the wash rinse with clean water to removed the soap residue.

**NOTE 3 :** Task is applicable to powerplant #'s 1 & 2.

**NOTE 4 :** All disconnected components to be flagged.

#### Instruction

1. Enter in aircraft technical log book "defect section column"
  - (a) 'Powerplant # 1 Cleaning, Desalination Wash to be carried out.  
Flow Divider/Dump Valve Fuel Drain Line and P3 Air Pressure Line disconnected'.
  - (b) 'Powerplant # 2 Cleaning, Desalination Wash to be carried out.  
Flow Divider/Dump Valve Fuel Drain Line and P3 Air Pressure Line disconnected'.
2. Raise separate work sheet in RUSADA for each powerplant.
3. Open access panels.
  - a. RH Nacelle: 423AL, 424AR, 427AB, 422AT.
  - b. LH Nacelle: 412AT, 413AL, 414AR, 417AB.
4. Disconnect flow divider/dump valve fuel drain line and install cap on drain connection.
5. Disconnect P3 air Pressure sensing tube at intercompresor case end and discard gasket. Install blank over end of tube. Discard Gaskets and "O" Rings removed.
6. Carry out the remainder of performance recovery washes in accordance with
  - a) P&WC MM 72-00-00, Engine Cleaning, Subpart (11) (pages 716-719)
7. All the consumable eg: Gasket's, "O"Ring's to be replaced upon of completion of task.
8. Removed cap on drain connection along with the plastic bag at P3 line.
9. Reconnect flow divider/dump valve fuel drain line and P3 Line.

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Nov 2012

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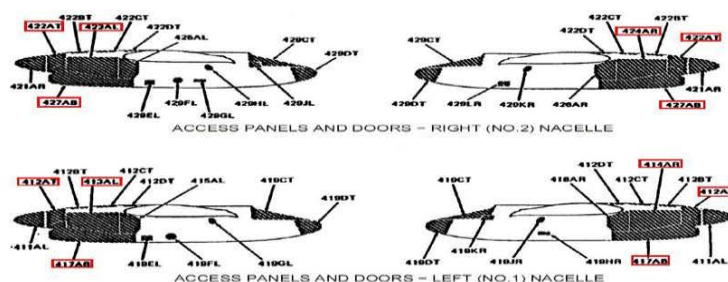


### Technical Information Bulletin

10. Close access panels
  - a. RH Nacelle: 423AL, 424AR, 427AB, 422AT.
  - b. LH Nacelle: 412AT, 413AL, 414AR, 417AB.
11. Carry out engine-drying run and leak checks.
12. Enter in technical log "action take section".
  - (a) "Powerplant # 1 Cleaning Desalination Wash c/o I.A.W P&WC MM 72-00-00, subpart (11) Flow Divider/Dump Valve Fuel Drain Line and P3 Air Pressure Line Re-connected "worksheet # XXXXXXXX refers.
  - (b) "Powerplant # 2 Cleaning Desalination Wash c/o I.A.W P&WC MM 72-00-00, subpart (11) Flow Divider/Dump Valve Fuel Drain Line and P3 Air Pressure Line Re-connected "worksheet # XXXXXXXX refers.
13. Each Powerplant Cleaning Desalination wash to be accomplished by two different engineers.
14. Each Powerplant to be certified release to service by independent engineer.
15. Duplicate inspection to be raised and carried out as per GEN 39.
  - a. "Powerplant # 1 Flow Divider/Dump Valve Fuel Drain Line and P3 Air pressure Line connection & security".
  - b. "Powerplant # 2 Flow Divider/Dump Valve Fuel Drain Line and P3 Air pressure Line connection & security".

**NOTE** All Abu Dhabi Aviation PW123 engines are post:

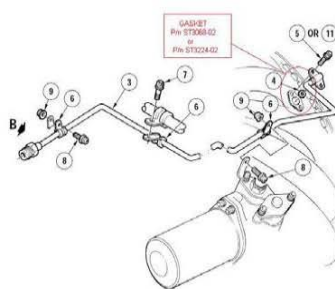
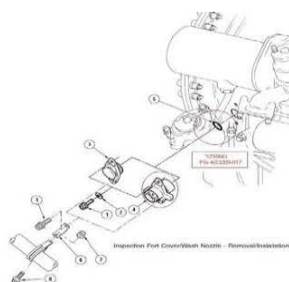
- ✓ SB20948
- ✓ SB21053
- ✓ SB21136



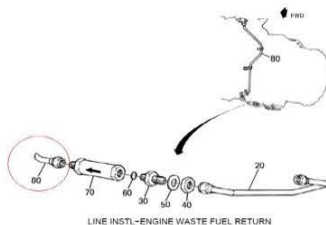


## Technical Information Bulletin

### Engine Cleaning, Desalination Wash



P3 and Overspeed Governor Pressure Sensing Tubes - Removal/Installation



\_\_\_\_\_  
Engineering Director